Chapter 16

Imaging Features

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Introduction

This chapter reviews LI-RADS imaging features and how they are used to assign categories.

The chapter begins with a discussion of basic concepts and then provides systematic description of all LI-RADS imaging features, which are classified as follows:

- Major features
- Ancillary features
- LR-M features
- TIV features

These classes of features are summarized briefly below and on the next page.

Major features

- These are used to assign LR-3, LR-4, and LR-5 categories to observations reflecting their relative probability of being HCC (see *CT/MRI Diagnostic Table*).
- Similar to other diagnostic systems, LI-RADS relies **exclusively on major features for categorizing observations as LR-5**.
- List of major features:
  - Nonrim arterial phase hyperenhancement (APHE)
  - Nonperipheral washout appearance
  - Enhancing capsule appearance
  - Size
  - Threshold growth

Ancillary features

- These are used **optionally at the radiologist's discretion** to adjust category (for LR-1, LR-2, LR-3, LR-4, or LR-5 observations), increase diagnostic confidence, or detect observations difficult to visualize on other sequences.
- Ancillary features are subdivided into those favoring malignancy in general, favoring HCC in particular, or favoring benignity.
- Ancillary features favoring malignancy in general or HCC in particular can be used to **upgrade** LR-1, LR-2, or LR-3 **by one category** to to LR-2, LR-3, or LR-4 respectively. They **cannot be used to upgrade LR-4 to LR-5**.
- Ancillary features favoring benignity can be used to **downgrade** LR-2, LR-3, LR-4, or LR-5 **by one category** to to LR-1, LR-2, LR-3, or LR-4 respectively.
- List of ancillary features: see *pages 16-254, 16-308* and *16-336*.

Introduction

LR-M features

- These are used to assign a category of LR-M. They indicate a high probability of malignancy but are not specific for HCC.

- LR-M observations have a substantial possibility of being a malignancy other than HCC.

- There are two types of LR-M features:

  - Targetoid LR-M features

    - Targetoid dynamic enhancement: rim APHE, peripheral washout appearance, delayed central enhancement
    - Targetoid appearance on DWI
    - Targetoid appearance on TP and/or HBP

  - Nontargetoid LR-M features

    - Infiltrative appearance
    - Marked diffusion restriction
    - Necrosis or severe ischemia
    - Other feature that in radiologist's judgment suggests non-HCC malignancy (specify in report).

TIV features

- The most important TIV feature is enhancing soft tissue in vein. This feature is necessary and sufficient to categorize an observation as LR-TIV. A parenchymal mass may or may not be seen.

- Several other features suggest the possibility of TIV, but do not establish its diagnosis. If present, such features should prompt the radiologist to scrutinize the vein for enhancing sift tissue.

  - Examples of suggestive features: occluded vein with ill-defined walls, occluded vein with restricted diffusion, occluded or obscured vein in contiguity with malignant parenchymal mass, heterogeneous vein enhancement not attributable to artifact

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Comment

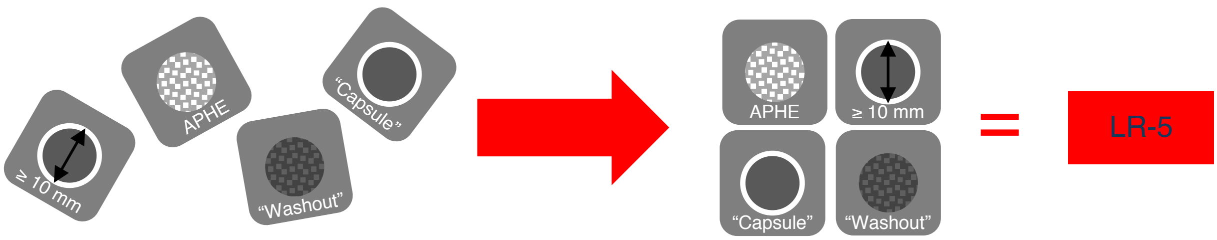
- Many other imaging features are commonly used in describing hepatic observations, but they are not applied formally in assigning or adjusting LI-RADS categories and therefore not defined in the LI-RADS v2018 manual.

- Examples include but are not limited to: CT hypoattenuatation, isoattenuation, hyperattenuation; T1 hypointensity, isointensity, or hyperintensity; T2 isointensity or mild hypointensity; HBP hyperintensity.

Basic Concepts

Imaging features are like building blocks

Just like building blocks are used to create buildings, imaging features are used to assign LI-RADS categories. With few exceptions (see below), individual imaging features by themselves do not suffice to assign LI-RADS categories. Instead, multiple imaging features usually are needed.



Exceptions: by themselves, some imaging features <u>suffice</u> to assign a LI-RADS category

Imaging features that by themselves suffice to assign a LI-RADS category

• Enhancing soft tissue within lumen of vein	By itself, suffices to assign LR-TIV
• Rim APHE • Peripheral "washout" • Delayed central enhancement • Targetoid appearance on DWI • Targetoid appearance in HBP	By itself, each of these suffices to assign LR-M
• Spontaneous disappearance	By itself, this feature suffices to assign LR-1

Some imaging features are <u>required</u> to assign a LI-RADS category

Another concept is that some imaging features are required for assigning LI-RADS categories that reflect 100% certainty (i.e., LR-5 and LR-TIV):

• Enhancing soft tissue within lumen of vein	Required for LR-TIV
• Nonrim APHE • Size ≥ 10 mm	Required for LR-5

Some of these concepts are illustrated on the next two pages

Basic Concepts

Various imaging features may be required, additional, or sufficient for assigning LR-5, LR-M, or LR-TIV categories, respectively. (See *Chapter 8* for discussion of categories).

Feature	Category	Comments	
Nonrim APHE Size ≥ 10 mm	LR-5	**Required**	Both of these features are required for LR-5. Only observations with both of these features can be categorized LR-5.
Nonperipheral WO Threshold growth Enhancing "capsule"	LR-5	**Additional**	These features are additional for LR-5. Observations with nonrim APHE and size ≥ 10 mm (required features) can be categorized LR-5 if there are additional features.
Rim APHE Peripheral WO Delayed central enhancement Target restriction Target HBP	LR-M	**Sufficient**	These features are sufficient for LR-M. Observations with any of these features are categorized LR-M.
Enhancing soft tissue in vein	LR-TIV	**Required & sufficient**	This feature is required and sufficient for LR-TIV.

Basic Concepts

By itself, each imaging feature provides a differential diagnosis, not a unique diagnosis, in high-risk patients. Examples are provided below for some LI-RADS features.

Feature	Differential diagnosis in high-risk patient for each feature *by itself*
Nonrim APHE	HCC, cHCC-CCA, small iCCA, dysplastic nodule, arterioportal shunt, rapidly enhancing hemangioma
Size ≥ 10 mm	Nonspecific
Enhancing “capsule”	HCC, cHCC-CCA, abscess
Nonperipheral “washout”	HCC, cHCC-CCA, small iCCA, dysplastic nodule
Threshold growth	HCC, cHCC-CCA, iCCA, other non-HCC malignancy
Rim APHE	Atypical HCC, iCCA, cHCC-CCA, other non-HCC malignancy, abscess
Peripheral “washout”	Atypical HCC, iCCA, cHCC-CCA, other non-HCC malignancy
Delayed central enhancement	Atypical HCC, iCCA, cHCC-CCA, other non-HCC malignancy, inflammatory pseudotumor
Target restriction	Atypical HCC, iCCA, cHCC-CCA, other non-HCC malignancy, abscess
Target HBP	Atypical HCC, iCCA, cHCC-CCA, other non-HCC malignancy
Enhancing soft tissue in vein	Common: HCC Uncommon: iCCA, cHCC-CCA

Basic Concepts: Major Features

Overview

LI-RADS uses major features to assign LR-3, LR-4, and LR-5 categories to observations reflecting their relative probability of being HCC (see *CT/MRI Diagnostic Table*) in high-risk patients. For more information on LI-RADS categories, see *Chapter 8*.

Two key concepts

No individual major feature provides 100% positive predictive value (PPV) for HCC.

Although no individual feature provides 100% PPV for HCC, the major features in appropriate combination do provide 100% PPV (LR-5 criteria) in high-risk patients.

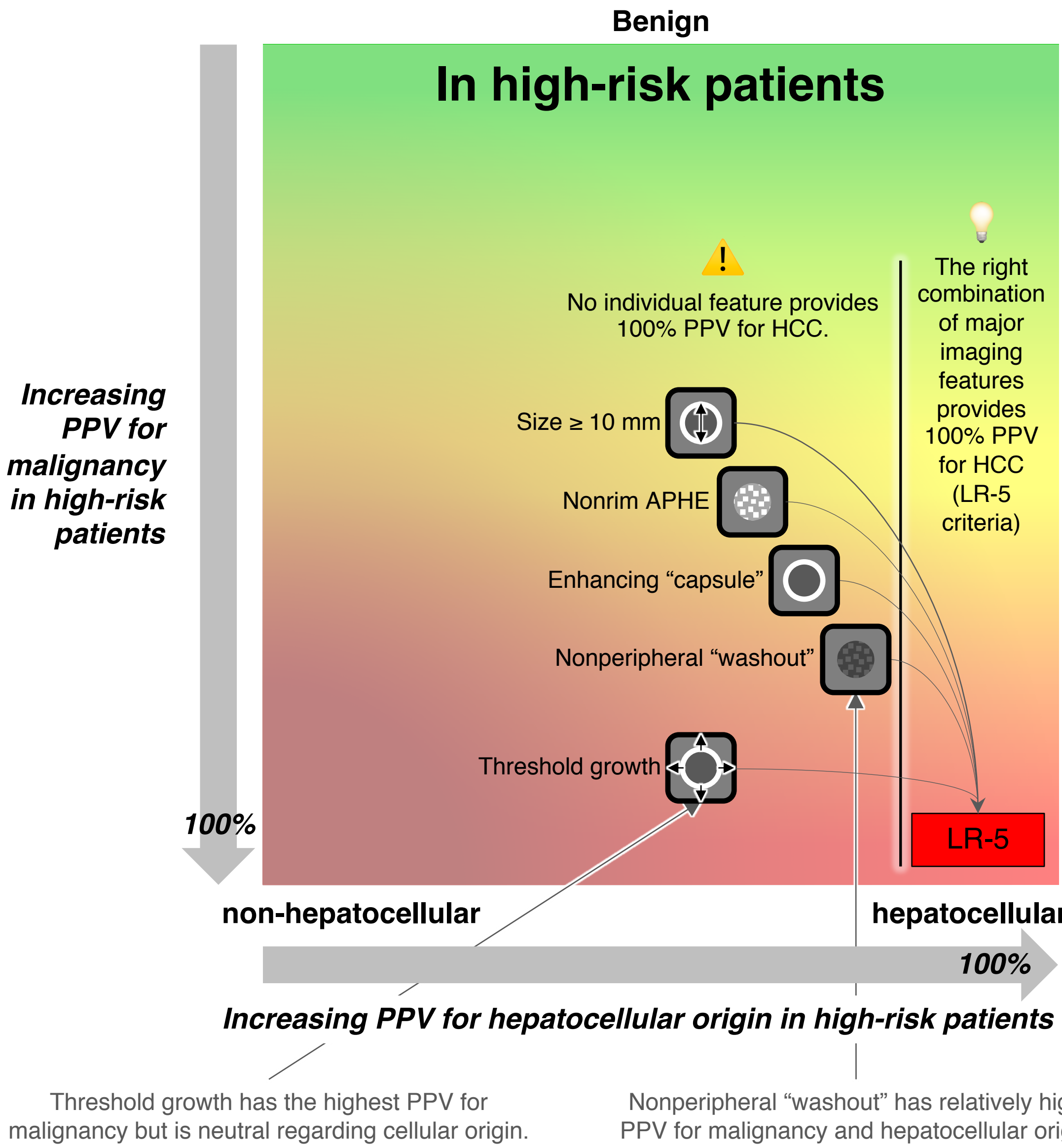


Figure illustrates for each major imaging feature its relative positive predictive value (PPV) for malignancy (y-axis) and for hepatocellular origin (x-axis) in patients with cirrhosis or chronic HBV

Basic Concepts: Major Features

A third key concept

LI-RADS criteria do NOT apply in general population.

- Explanation:
    - In the general population, the pretest probability of HCC is so low that an observation meeting imaging criteria for HCC may not be HCC but rather an atypical manifestation of another entity.
- For more information on the LI-RADS population, see *Chapter 2*.

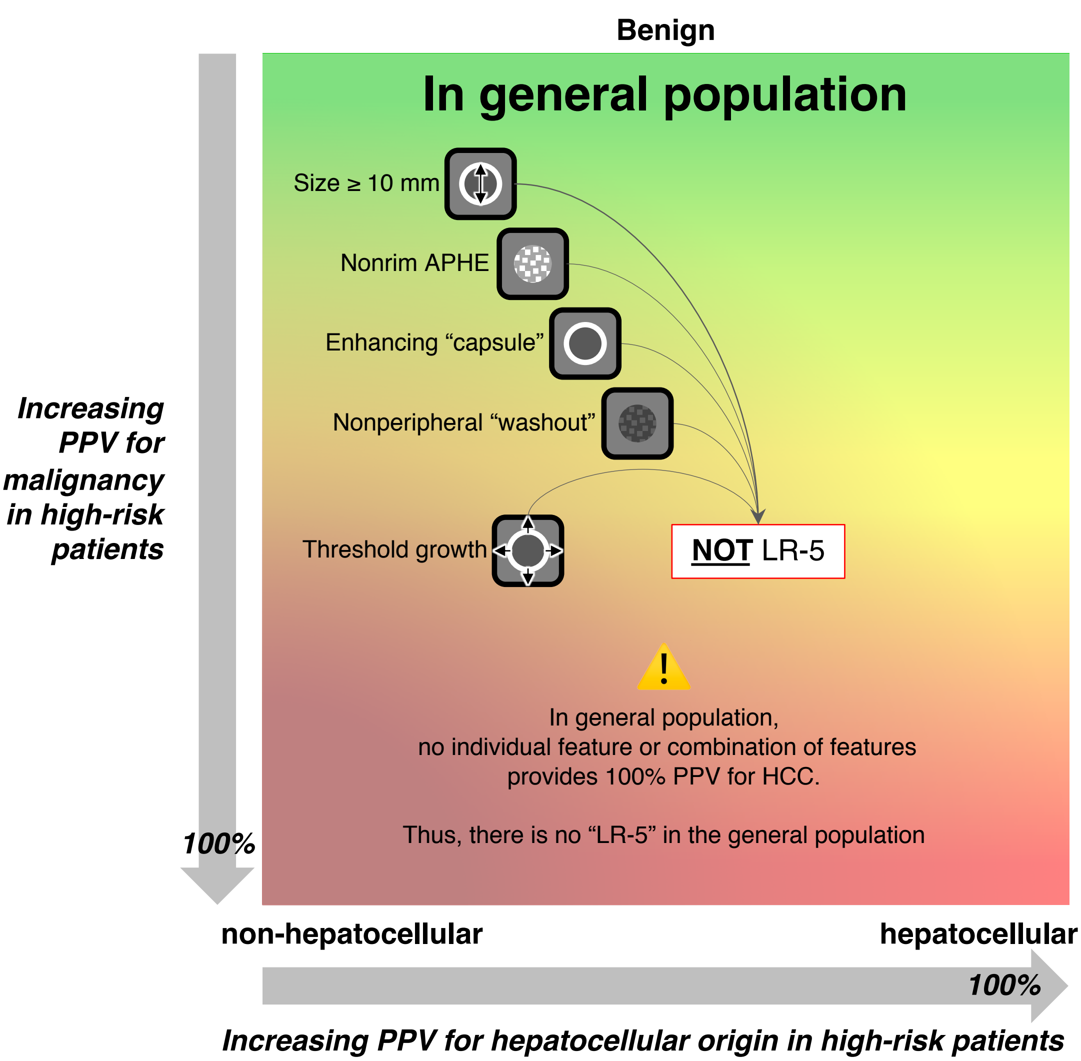


Figure illustrates that LI-RADS major features and criteria should NOT be applied in the general population.

Basic Concepts: LR-M Features

Overview

While HCC is the most common malignancy in cirrhosis, patients with cirrhosis are at higher risk than the general population for other primary malignancies, such as iCCA and cHCC-CCA. Furthermore, although metastases are rare in cirrhosis, they can occur. Thus, the differential diagnosis of malignant neoplasms in cirrhosis includes HCC, iCCA, cHCC-CCA, and uncommonly, other tumors. See *Chapter 5* for more information on malignancy in cirrhosis.

LI-RADS uses LR-M features to categorize observations with a high probability of being malignant and a substantial possibility of being a malignancy other than HCC.

Based on emerging evidence:

- About 60% of LR-M observations are non-HCC malignancies. Thus, most LR-M observations are malignant neoplasms other than HCC.
- About 1/3 of LR-M observations are HCC with atypical imaging features. Thus, LR-M does not exclude HCC.
- About 5% of LR-M observations are benign. Thus, LR-M indicates high but not 100% certainty of malignancy.

For more information on the LR-M category, see *Chapter 8, page 14*.

LR-M features are divided into targetoid LR-M features and non-targetoid LR-M features

Targetoid LR-M features	These are family of imaging features characteristic of non-HCC malignancies and atypical of HCC. • These features include rim APHE (page 16-38), peripheral "washout" (page 16-125), delayed central enhancement (page 16-221), targetoid appearance in transitional and/or hepatobiliary phase (page 16-227), targetoid diffusion restriction (page 16-234). • They are thought to reflect peripheral arterialization and hypercellularity in conjunction with central fibrosis or ischemia.
Nontargetoid LR-M features	These are an assortment of imaging features characteristic of malignancy. Unlike targetoid LR-M features, they are commonly seen in HCCs (especially aggressive or poorly differentiated HCCs) as well as non-HCC malignancies such as iCCA. • These features include marked diffusion restriction (page 16-241), infiltrative appearance (page 16-241), necrosis or severe ischemia (page 16-241).

Basic Concepts: LR-M Features

Each targetoid LR-M feature, by itself, is sufficient for LR-M categorization:

Presence of at least one LR-M feature should prompt LR-M categorization, regardless of other features.

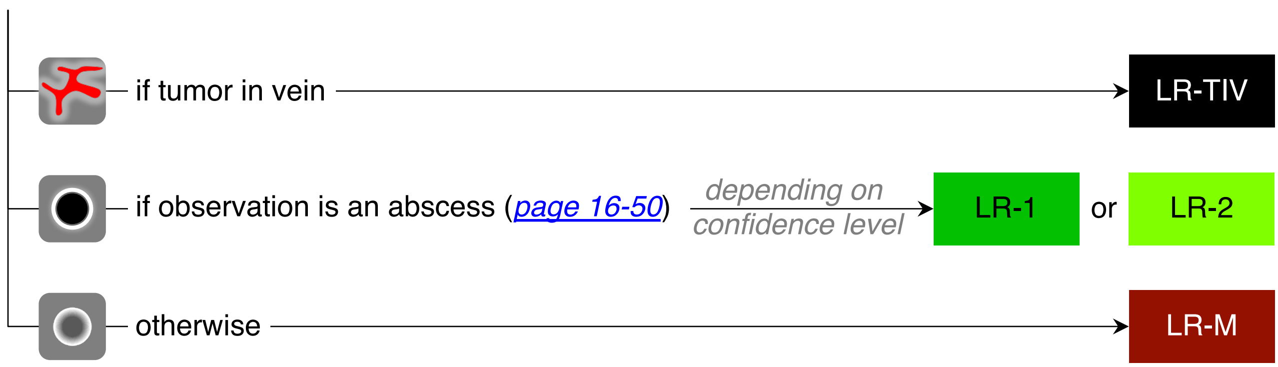
Rationale:

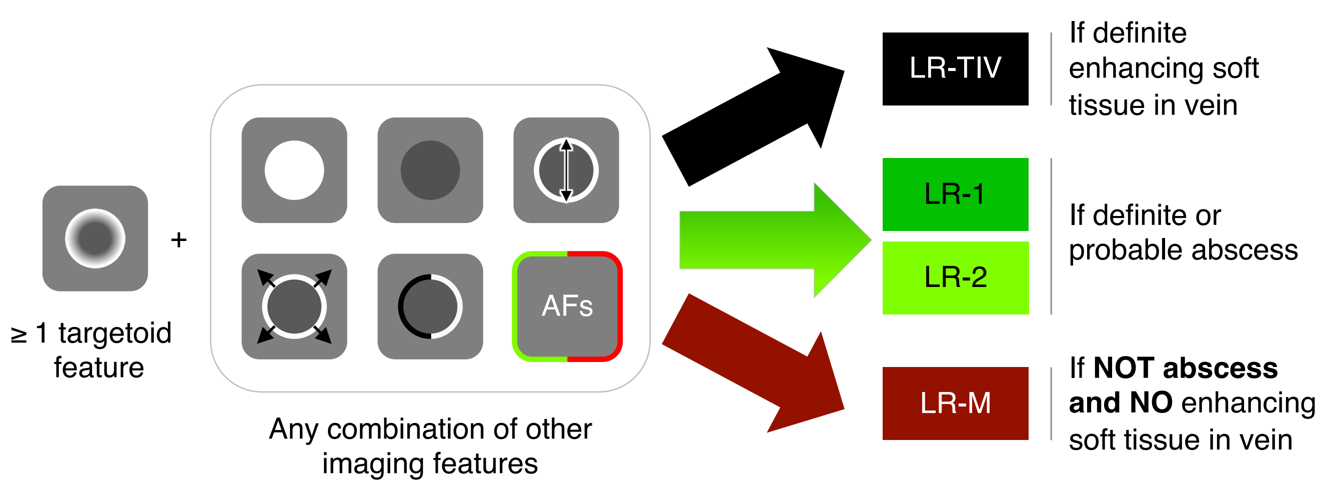
- These features are characteristic of non-HCC malignancy and atypical of HCC.

Exceptions:

- If observation is path proven, report path diagnosis, not LI-RADS category.
- If there is definite tumor in vein, categorize as LR-TIV.
- If the observation is thought to be an abscess (see *page 16-50*), categorize as LR-1 or LR-2 depending on confidence level.

Nonpath-proven observation with **at least one targetoid feature**





Basic Concepts: LR-M Features

Each nontargetoid LR-M feature, by itself, is sufficient for LR-M categorization:

Presence of at least one LR-M feature should prompt LR-M categorization, regardless of other features.

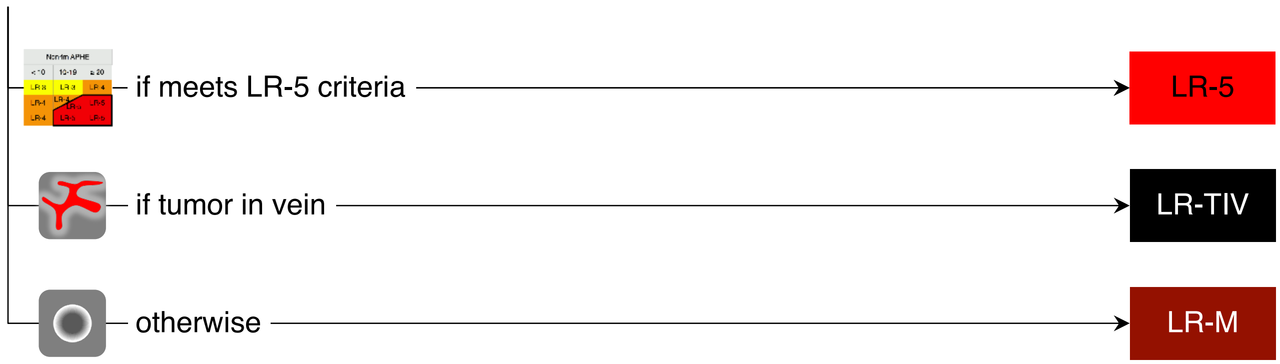
Rationale:

- Nontargetoid LR-M features are highly suggestive of malignancy but are not specific for any particular tumor type, being commonly encountered in aggressive or poorly differentiated HCCs, as well as in non-HCC malignancies.
- Since they indicate high probability of malignancy but are not specific for HCC, they should prompt LR-M categorization.

Exceptions:

- If observation is path proven, report path diagnosis, not LI-RADS category.
- If the observation meets LR-5 criteria, categorize as LR-5.
    - Rationale: since the features are commonly encountered in aggressive or poorly differentiated HCC, their presence does not override LR-5 categorization.
    - Thus, an observation meeting LR-5 criteria and having one or more of these features can be interpreted as definite HCC.
- If there is tumor in vein, categorize as LR-TIV.

Nonpath-proven observation with **at least one nontargetoid feature**



Basic Concepts: LR-TIV Features

Overview

Tumor in vein refers to the unequivocal invasion by a malignant neoplasm into a major vein (portal, hepatic, cava, or combination). In high-risk patients, the most common cause of vascular invasion is HCC, although iCCA, cHCC-CCA, and rarely other malignancies may invade veins.

The recognition of tumor in vein is important. It reveals that the tumor is biologically aggressive, has accessed the blood stream, and has probably metastasized outside the liver. For these reasons, tumor in vein indicates a poor prognosis, narrows the number of treatment options, and is a contraindication to liver transplant.

LI-RADS uses LR-TIV features to categorize observations with tumor in vein.

There are two types of LR-TIV features:

- Enhancing soft tissue in vein
- Features suggestive of tumor in vein

Enhancing soft tissue in vein

The unequivocal presence of enhancing soft tissue in a vein is necessary and sufficient to categorize an observation as LR-TIV.

Any observation with this feature should be categorized LR-TIV, regardless of the presence or absence or any other feature and regardless of visualization of a parenchymal mass.

See *page 16-243* for more information.

Features suggestive of tumor in vein

These features suggest the possibility of TIV, but do not establish its diagnosis. If present, such features should prompt the radiologist to scrutinize the vein for enhancing soft tissue.

- Examples:
  - Occluded vein with ill-defined walls
  - Occluded vein with restricted diffusion
  - Occluded or obscured vein in contiguity with malignant parenchymal mass
  - Heterogeneous vein enhancement not attributable to artifact

See *page 16-249* for more information.

AFs

Basic Concepts: Ancillary Features

Overview

As discussed earlier, LI-RADS uses **major features** to assign categories to observations reflecting their relative probability of being HCC (See *CT/MRI Diagnostic Table*).

Similar to the approach used by other diagnostic systems, LI-RADS relies exclusively on **major features** for categorizing observations as LR-5. **Ancillary features** are unique to LI-RADS.

They may be applied optionally at the user's discretion to:

- Adjust category of LR-1, LR-2, LR-3, LR-4, or LR-5 observations
- Increase diagnostic confidence
- Detect observations difficult to visualize on other sequences

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If applied to adjust category they should be applied following standard rules

- See *page 16-14*.

They should not be used to adjust the category of LR-M or LR-TIV observations

- Caveat: if incompatible with the assigned category, ancillary features can prompt the radiologist to reevaluate.
  - Example: if a LR-M observation is unequivocally smaller than on a prior exam, the radiologist should question the original category assignment, repeat the diagnostic algorithmic process, and consider other categories.

In LI-RADS v2018, ancillary features are divided into:

Favoring malignancy:

- These can be used to upgrade LR-1, LR-2, L-3 by one category to LR-2, LR-3, or LR-4, respectively. They cannot be used to upgrade LR-4 to LR-5.
  - These are subdivided into those that
    - favor malignancy in general (*page 16-254*)
    - those that favor HCC in particular (*page 16-308*)

Favoring benignity (*page 16-336*):

- These can be used to downgrade LR-2, L-3, LR-4, or LR-5 by one category to LR-1, LR-2, LR-3, or LR-4, respectively.

Basic Concepts: Ancillary Features

The applicability of ancillary features depends on the imaging method:

Some features are applicable to CT, MRI with extracellular agents, and MRI with hepatobiliary agents.

Some features are applicable only to MRI with extracellular agents and MRI with hepatobiliary agents.

Some features are applicable only to MRI with hepatobiliary agents.

See *pages 16-254, 16-308, 16-336.*

The application of ancillary features is optional in the current version of LI-RADS.

Versions of LI-RADS prior to v2017 and v2018 mandated the application of ancillary features.

However, there is currently a lack of scientific data supporting the mandatory use of ancillary features.

Moreover, LI-RADS recognizes that mandating use of AFs may contribute to the perceived complexity of LI-RADS and may discourage its adoption.

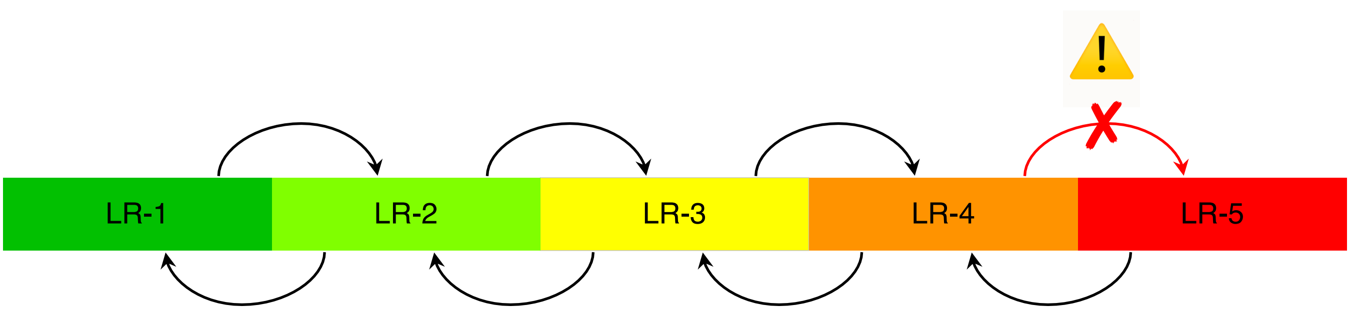
To encourage adoption of LI-RADS and since the use of LI-RADS without ancillary features is preferable to not using LI-RADS at all, LI-RADS has made ancillary features optional.

Basic Concepts: Ancillary Features

If ancillary features (AFs) are applied to adjust category, the rules below should be followed:

- AFs may be used to adjust the category of LR-1, LR-2, LR-3, LR-4, or LR-5 observations.
- AFs do not exclude LR-M or LR-TIV, and they should not not be used to change LR-M or LR-TIV to a different category.
  - Caveat: if incompatible with the assigned category, ancillary features can prompt the radiologist to reevaluate.
- AFs may be used to upgrade or downgrade by one category only, even when multiple concordant AFs are present (i.e. all favoring malignancy or all favoring benignity).
- If AFs favoring both malignancy and benignity are present, the category should be left unchanged.
- AFs cannot be used to upgrade LR-4 to LR-5.
- Absence of ancillary features favoring malignancy cannot be used to downgrade the category.
- Absence of ancillary features favoring benignity cannot be used to upgrade the category.

≥ 1 AF favoring malignancy: upgrade by 1 category, up to LR-4
(Absence of these AFs cannot be used to downgrade the category)



≥ 1 AF favoring benignity: downgrade by 1 category
(Absence of these AFs cannot be used to upgrade the category)

If ≥ 1 AF favoring malignancy <u>and</u> ≥ 1 AF favoring benignity: do **not** adjust category

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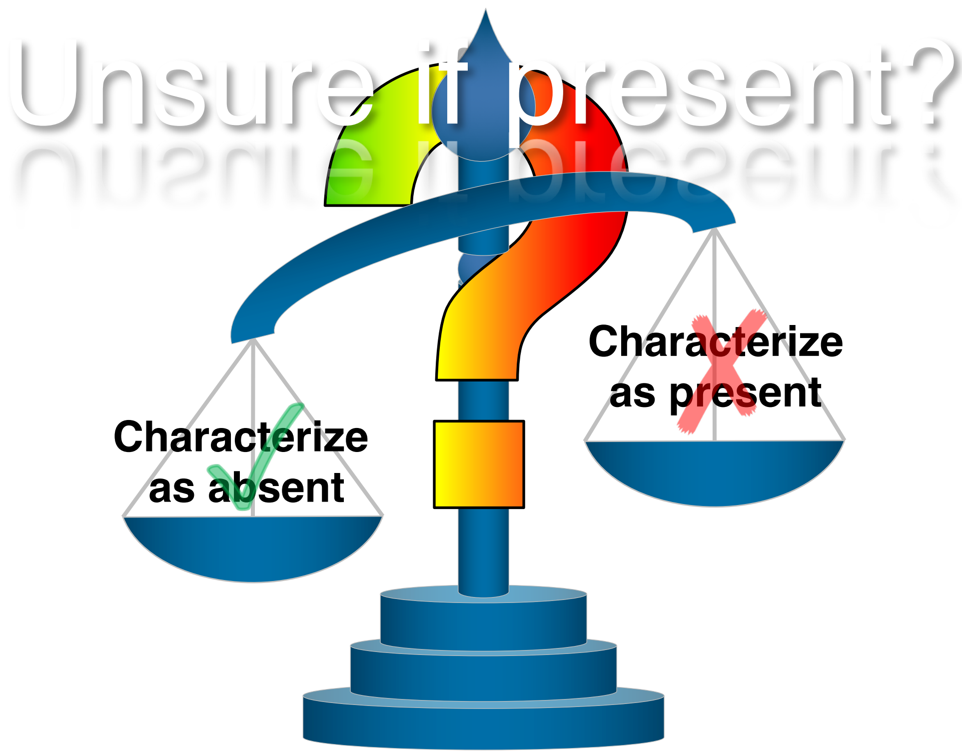
- *AFs cannot be used to upgrade LR-4 to LR-5.*
- *If unsure that an ancillary feature is present, characterize as absent.*

Basic Concepts:

General rule for characterizing any feature when there is uncertainty

If unsure that a feature is present → characterize that feature as absent



Rationale:

LI-RADS requires certainty about the presence of features to help ensure their specificity

Imaging Features - Format

Definition
This section provides definition of the feature

Synonyms
This section includes synonyms used in the literature for the feature

Terminology
This section provides rationale for the preferred term

Applicable modalities
This section lists modalities on which the feature can be assessed

Type of feature
This section lists the type of feature

Effect on categorization
This section describes how presence of the feature affects the categorization.

Biological basis
This section describes biological basis for the feature

Summary of evidence
This section summarizes the literature supporting the use of the feature

Characterization
This section provides illustrations of the feature, including schematic and cases

If unsure
This section explains how to characterize features when there is uncertainty

- General rule for characterizing any feature when there is uncertainty – see page 16-15.

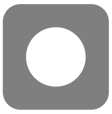
Pitfalls & practical considerations
This section discusses the potential pitfalls and solutions for characterization of the feature

References
This section lists the relevant references

Arterial Phase Hyperenhancement (APHE) & its Subtypes

Feature | **Definition** | *Page*

APHE



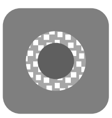
Enhancement in arterial phase unequivocally greater in whole or in part than liver. Enhancing part must be brighter than liver in arterial phase.

APHE may be rim or nonrim (see below).

16-18

APHE Subtypes

Rim APHE



Spatially defined subtype of APHE in which APHE is most pronounced in observation periphery. Rim of enhancement in the arterial phase must be continuous but need not be complete.

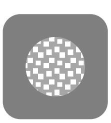
Rim APHE is a targetoid LR-M feature. By itself, rim APHE suffices for LR-M categorization. Thus, all untreated observations with rim APHE should be categorized LR-M, with 3 exceptions.

Exceptions:
- If there is tumor in vein, categorize as LR-TIV.
- If observation is path-proven nonhepatocellular benign entity or malignant neoplasm, report path diagnosis, not LI-RADS category.
- If observation is an abscess, categorize as LR-1 or LR-2

Rim APHE is not required for LR-M categorization. Thus, some observations can be categorized LR-M even if they lack rim APHE.

16-38

Nonrim APHE



Spatially defined subtype of APHE in which APHE is NOT most pronounced in observation periphery. Enhancement can be diffuse and homogeneous, diffuse and heterogeneous, scattered, nodule-in-nodule, or mosaic.

Nonrim APHE is required for LR-5 categorization. The absence of APHE excludes LR-5 categorization. Only observations with APHE can be categorized LR-5.

By itself, nonrim APHE does **not** suffice for LR-5 categorization. Thus, observations with nonrim APHE can be categorized LR-5 only in combination with other features. See *CT/MRI Diagnostic Table*.

16-66

Caveat

16-63

Peripheral nodular discontinuous enhancement does not fit simply into above classification. This enhancement type suggests hemangioma. If arterial phase images show peripheral discontinuous nodular areas of enhancement, look for other features of hemangioma.

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Definition

Enhancement in arterial phase unequivocally greater in whole or in part than liver. Enhancing part must be brighter than liver in arterial phase.

APHE has two subtypes:

- Rim APHE: page 16-38
- Nonrim APHE: page 16-66

Synonyms

Arterial hypervascularity, hypervascularity in arterial phase, increased contrast enhancement in hepatic arterial phase, increased contrast enhancement in late hepatic arterial phase, hypervascularity, high attenuation area in arterial phase, contrast uptake in arterial phase, wash in

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Terminology

The term APHE is preferred since "APHE" is

- Modality independent
- A descriptor of observation appearance that makes no assumptions (which may be false or simplistic) about underlying physiology, such as vascularity

Depending on context, LI-RADS may use the term APHE to refer to APHE generically or, for simplicity, to refer specifically to nonrim APHE (the more common APHE subtype).

Applicable imaging methods

CT, MRI

Type of feature

Depends on spatial subtype of APHE:

- Rim APHE: targetoid LR-M feature, sufficient for LR-M, excludes LR-5 (page 16-9)
- Nonrim APHE: major feature of HCC, required for LR-5 (page 16-67)
- Caveat: Peripheral discontinuous nodular enhancement (page 16-63).

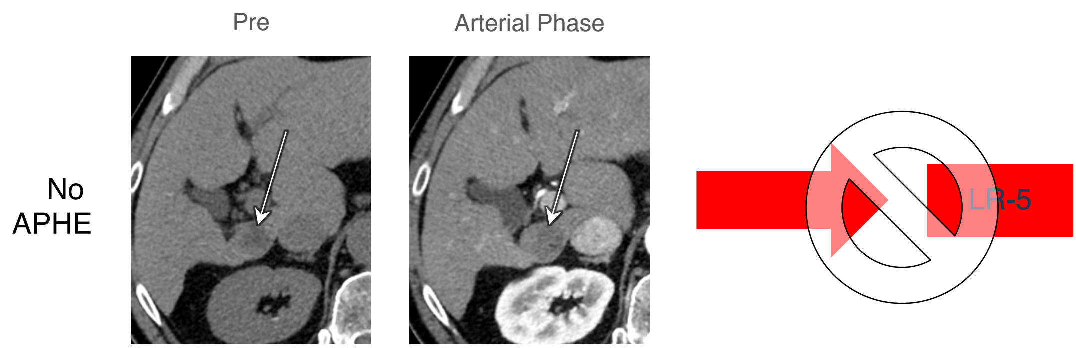
Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Effect on categorization

APHE is required for LR-5.

Only observations with APHE can be categorized LR-5. As a corollary, the absence of APHE precludes LR-5 categorization.

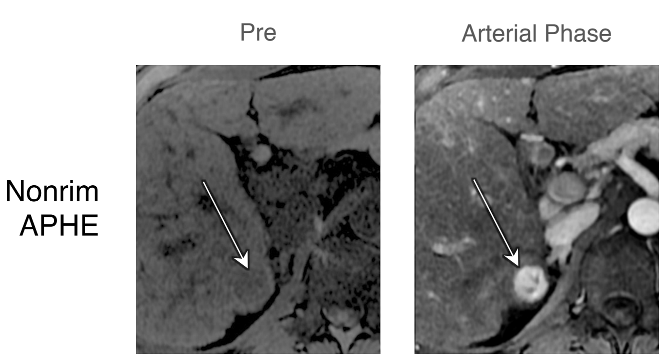


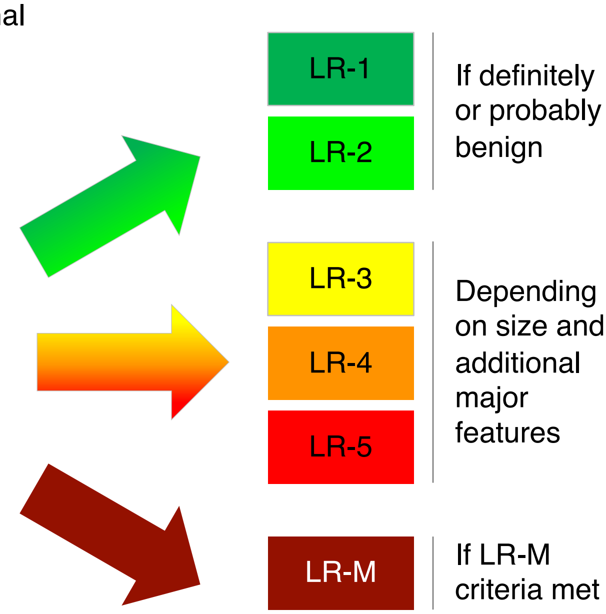
APHE is not sufficient for LR-5.

Observations with nonrim APHE *can* be other than LR-5.

For example, observations with nonrim APHE can be

- LR-1 or LR-2 (if definitely or probably benign)
- LR-M (if LR-M criteria met)
- LR-3, LR-4, LR-5 (depending on size and additional major features)





Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Effect on categorization (Cont'd)

Rim APHE is sufficient for LR-M.

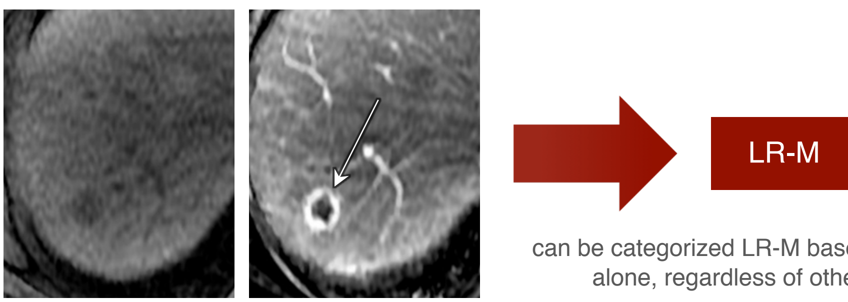
By itself, rim APHE is enough for LR-M. Thus, all untreated observations with rim APHE are LR-M, regardless of other imaging features.

Exceptions:

- If there is tumor in vein, categorize as LR-TIV.
- If observation is path proven, report path diagnosis, not LI-RADS category.
- If observation is an abscess, categorize as LR-1 or LR-2 depending on confidence level

Pre

Arterial Phase



Rim APHE

can be categorized LR-M based on rim APHE alone, regardless of other features

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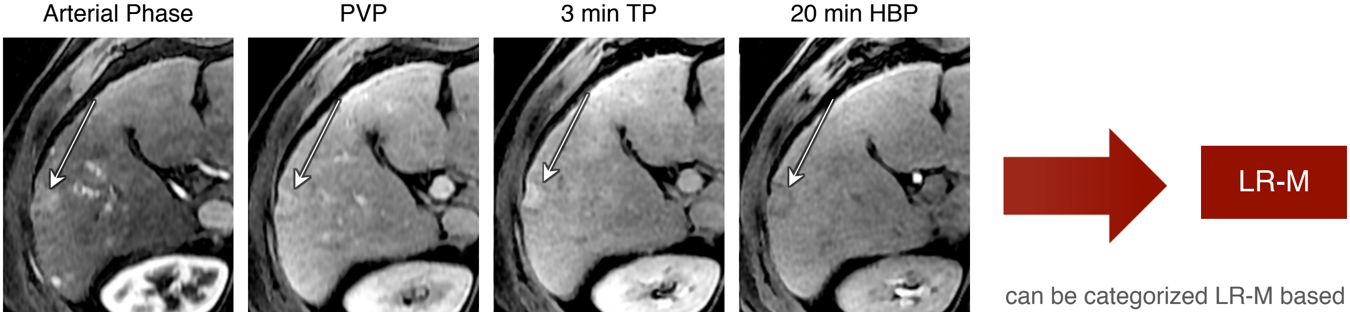
Rim APHE is not required for LR-M.

Observations without rim APHE can be LR-M if other LR-M features are present (see page 16-9).

Example: Observation with peripheral "washout" and HBP targetoid pattern but not rim APHE

Arterial Phase | PVP | 3 min TP | 20 min HBP



Nonrim APHE | Peripheral "washout" | 3-minute central enhancement | Targetoid HBP pattern

can be categorized LR-M based on other features, despite absence of rim APHE

Arterial Phase Hyperenhancement (APHE)

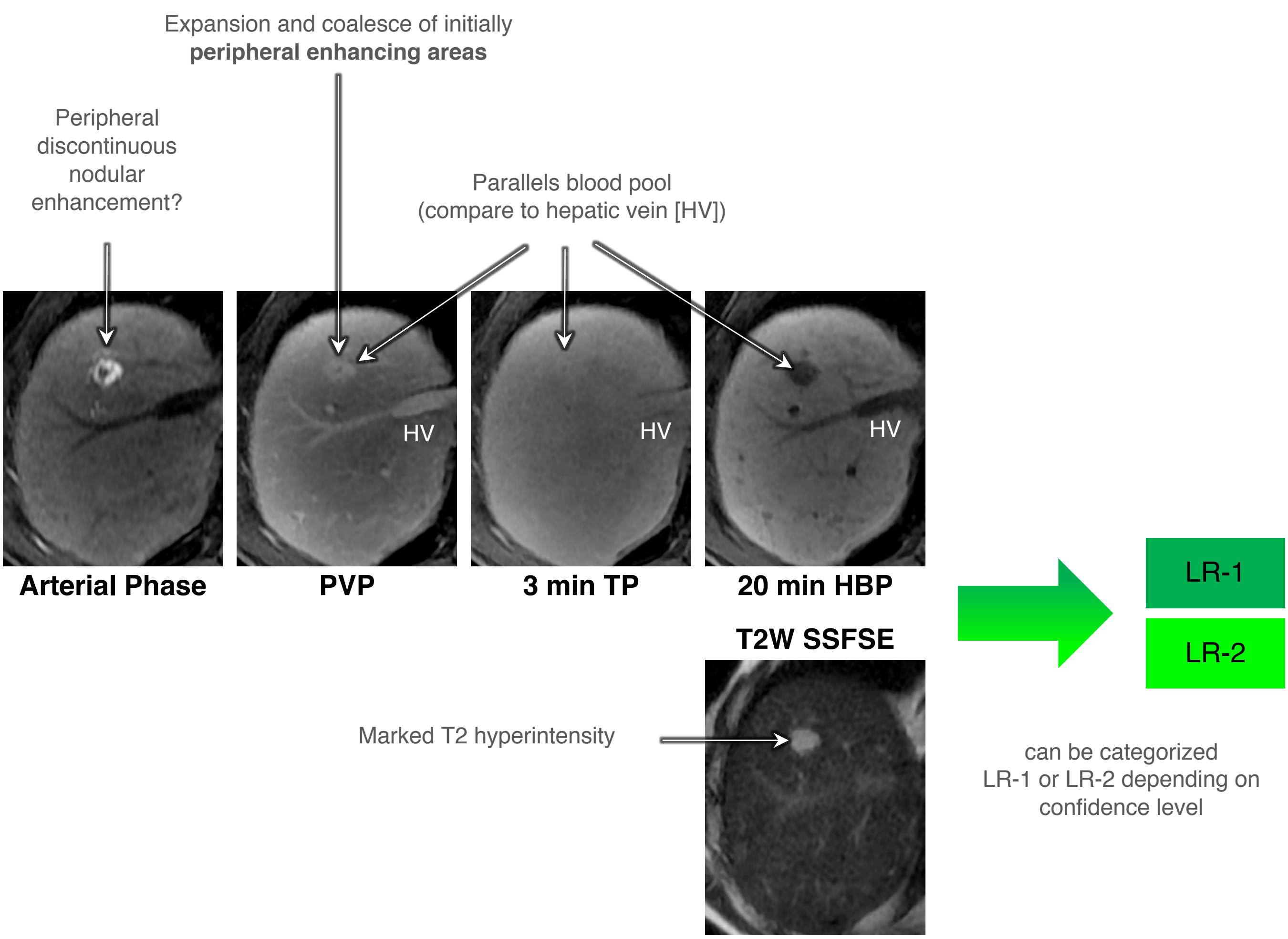
RADLEX ID: RID43355

Effect on categorization (Cont'd)

Caveat: If you see peripheral nodular enhancement, look for other features of hemangioma, such as

- Expansion and coalescence of initially peripheral enhancing areas
- Paralleling of blood pool
- Marked T2 hyperintensity (if MRI)

MRI with gadoxetate disodium in 63-year-old patient with well-compensated HCV cirrhosis



Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Biological basis

APHE has many mechanisms

- Formation of tumor arteries (neoangiogenesis). See Chapter 6.
    - The distribution of tumor arteries may be
        - Diffuse: most HCCs, some small iCCAs (< 20 mm)
        - Peripheral: most iCCAs
- Presence of large feeding arteries and arterioles in nonmalignant lesions
    - Some dysplastic nodules
    - Uncommon in cirrhosis: hemangiomas
    - Rare in cirrhosis: FNH, HCA

With these mechanisms, APHE occurs in mass itself

- Arterioportal shunting, which in turn may have many causes
    - Microscopic connections between hepatic arterioles and portal venules
    - Portal vein obstruction by extrinsic mass, intraluminal tumor, or bland thrombus: causes compensatory increase in arterial flow (hepatic arterial buffer response)
    - Arterioportal fistula (e.g., after a liver biopsy) = a direct connection between an artery and portal vein in the same portal triad)
- Third inflow (nonportal venous inflow, e.g., veins in peribiliary plexus)
- Hyperemia due to inflammation (e.g., around inflamed bile ducts and/or abscess, or adjacent to inflamed gall bladder)
- Siphon effect = increased arterial flow to entire vascular territory supplied by one or more arteries recruited by a tumor

With these mechanisms, APHE occurs

- In liver parenchyma
- Around or adjacent to a mass
- Not in mass itself

For more information on

- Rim APHE: see page 16-39.
- Nonrim APHE: see page 16-70.

Summary of evidence

For rim APHE: see page 16-40.
For nonrim APHE: see page 16-72.

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Characterization

Rim APHE and nonrim APHE are mutually exclusive subtypes of APHE

- If APHE is most pronounced in observation periphery, characterize as rim APHE, NOT nonrim APHE.

For more information on characterization of

- Rim APHE, *see page 16-41.*
- Nonrim APHE, *see page 16-73.*

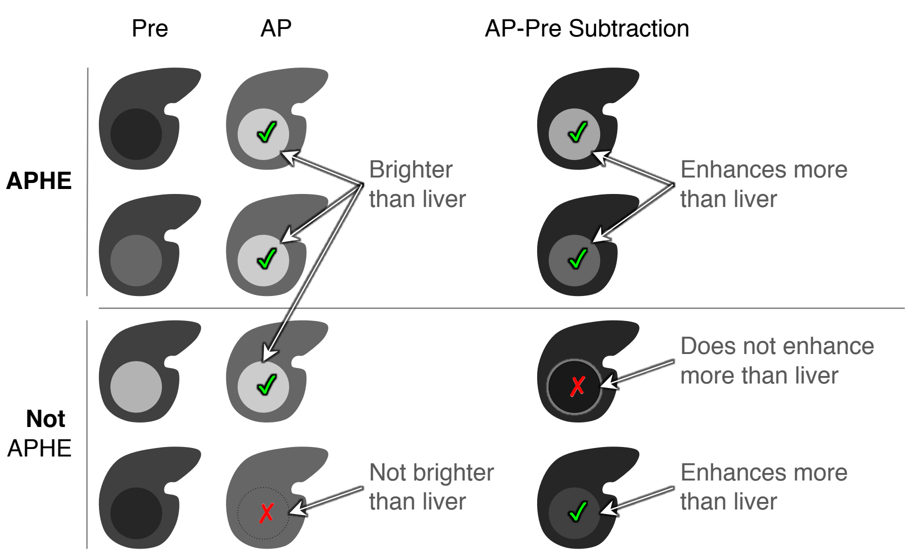
Characterize on arterial phase images. Late arterial phase images are usually more reliable for detecting APHE than early arterial phase images. See *page 16-32*.

APHE is present if **BOTH** of the following are met:

- Observation in whole or in part enhances more than liver in arterial phase [a]

  AND

- Enhancing part is brighter than liver in arterial phase



[a] To assess enhancement relative to liver, compare to precontrast image if available (precontrast imaging is mandatory for MRI, optional for CT; see *Chapter 12*.

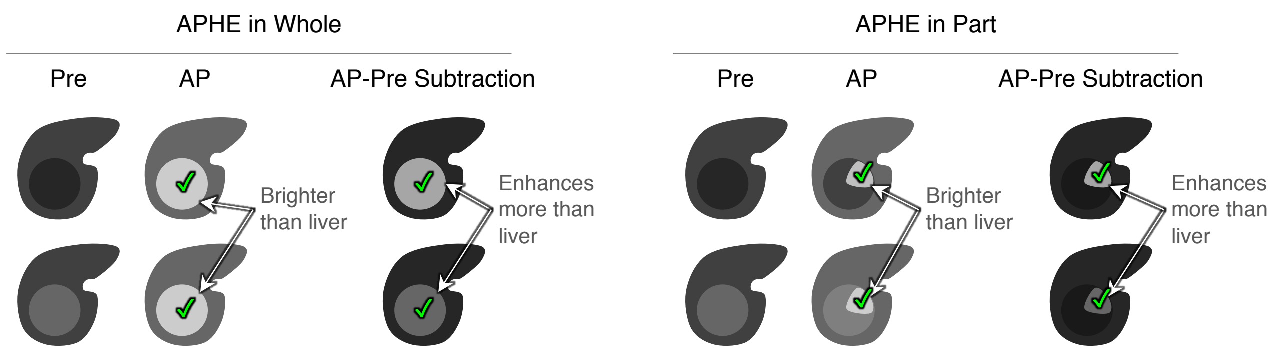
For observations that are T1 hyperintense precontrast, use of AP – Pre subtractions can help. See *page 16-26* for use of subtractions.

Arterial Phase Hyperenhancement (APHE)

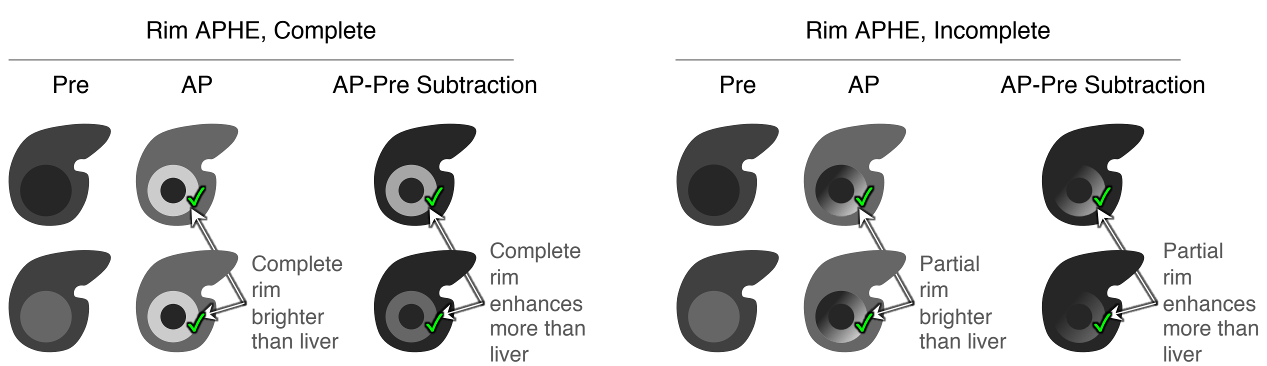
RADLEX ID: RID43355

Characterization (Cont'd)

APHE may be in whole or in part:



Rim APHE may be compete or incomplete



There is no minimum number of pixels to gauge whether APHE is present or if it is rim or nonrim.

- Rather, its presence and subtype must be unequivocal in the radiologist's judgment
- Rationale: there is no scientific data to guide an optimal threshold. Any imposed threshold would be arbitrary

Arterial Phase Hyperenhancement (APHE)

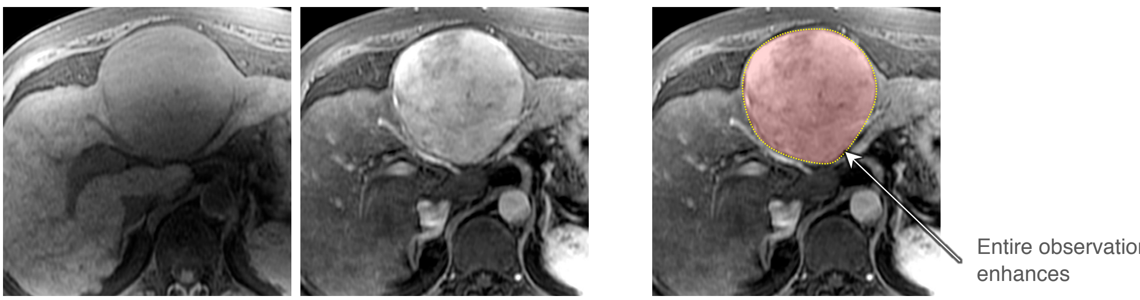
RADLEX ID: RID43355

Characterization (Cont'd)

APHE may be in whole:

Pre | AP | AP – Annotated

MRI
85 mm
observation



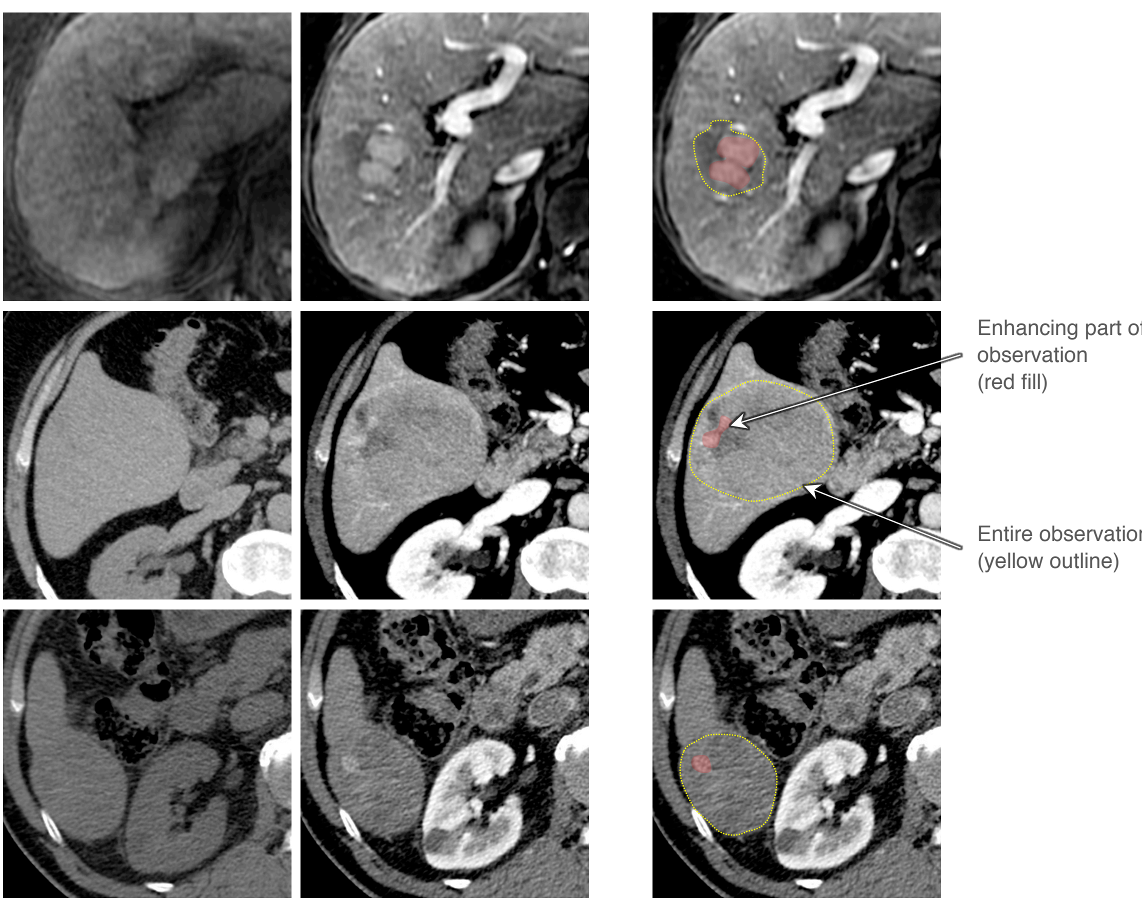
APHE may be in part:

Pre | AP | AP – Annotated

MRI
33 mm
observation

CT
82 mm
observation

CT
56 mm
observation



Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Characterization (Cont'd)

Use of subtractions to characterize APHE

For enhancing observations that are hyperintense precontrast, assessment of APHE can be challenging. For such observations and with care, subtractions (subs) may be used to assess APHE if and only if the precontrast images and the AP images are co-registered **AND** acquired with identical technique.

With caution, subtractions may be used to characterize APHE when AP/pre images are misregistered if amount of misregistration is small relative to region(s) being assessed for APHE.

See *Chapter 12, page 24* for definition of and instructions for performing subtractions.

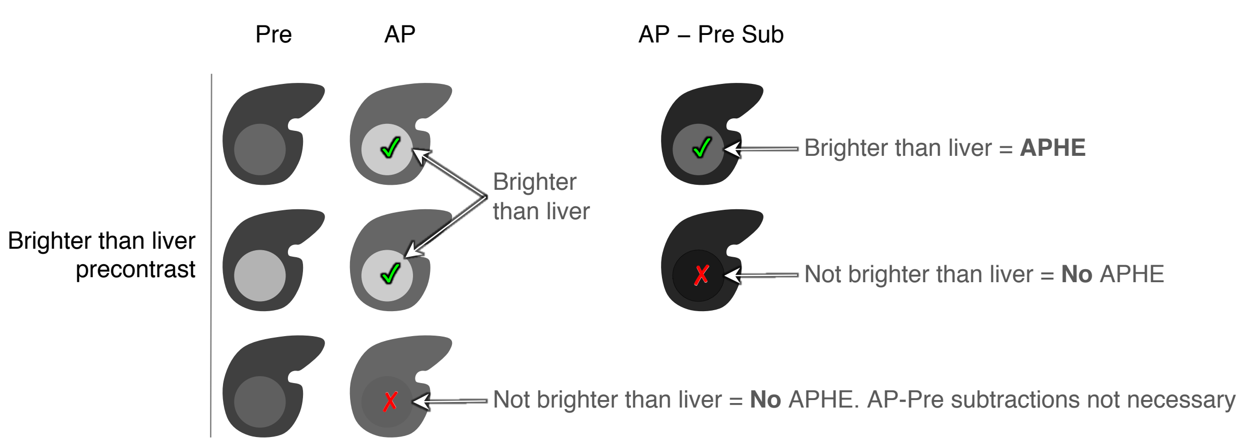
Interpretation of subtractions

Step 1.

Verify co-registration for each observation. If images for a particular observation are not co-registered, be cautious in using subtractions to characterize APHE for that observation.

Step 2.

Compare brightness of observation relative to liver on (AP – Pre) sub. Unequivocal brightness of observation relative to liver the sub is interpreted as APHE.



Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

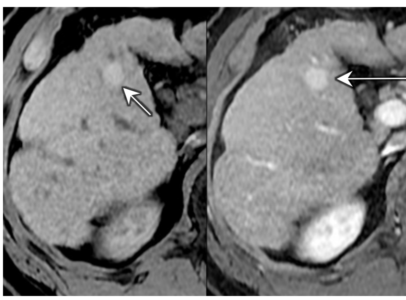
Characterization (Cont'd)

Interpretation of subtractions (Cont'd)

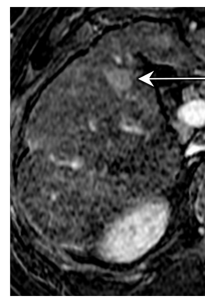
Examples: MRI

Pre | AP | AP – Pre Sub

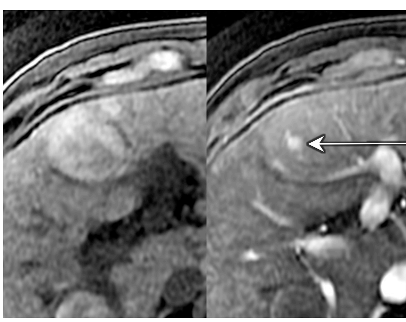
Brighter than liver precontrast



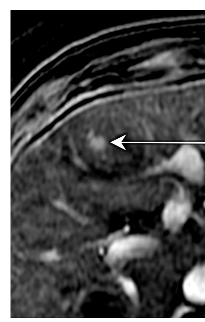
✓ definitely brighter than adjacent liver



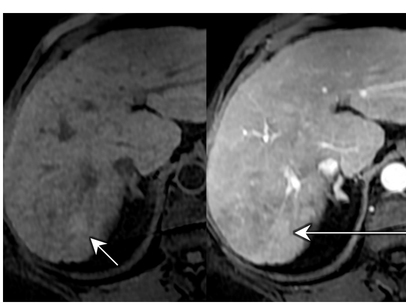
✓ definitely brighter than adjacent liver = **APHE**



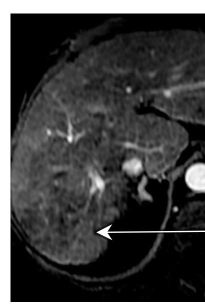
✓ part definitely brighter than adjacent liver



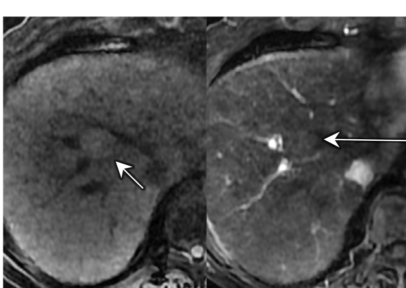
✓ part definitely brighter than adjacent liver



✓ definitely brighter than adjacent liver



✗ **NOT** definitely brighter than adjacent liver = **No** APHE



✗ **NOT** definitely brighter than adjacent liver = **No** APHE
Subtractions not necessary

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Characterization (Cont'd)

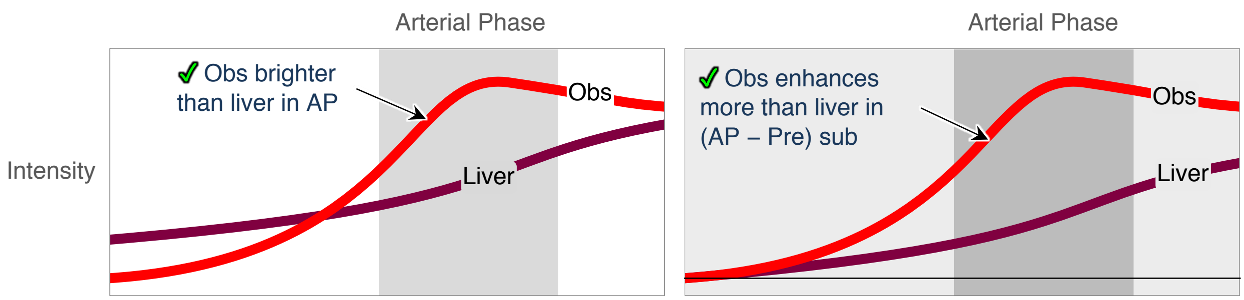
Subtraction concepts can be illustrated with time-intensity curves

Graphs on left illustrate idealized time-intensity curves of observation (obs) and background liver from time of contrast material injection through arterial phase.

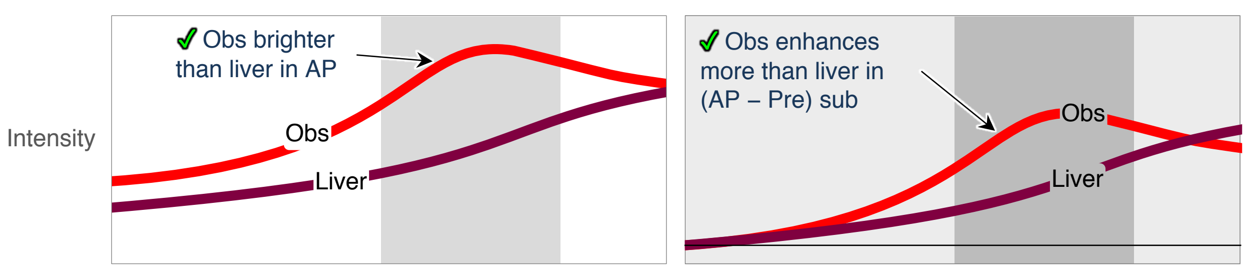
Graphs on right illustrate same time-intensity curves after subtraction from Pre (baseline) intensity. On subtractions, obs and liver start with zero intensity because their baseline signal was subtracted.

Precontrast hypointense observation (obs) with APHE

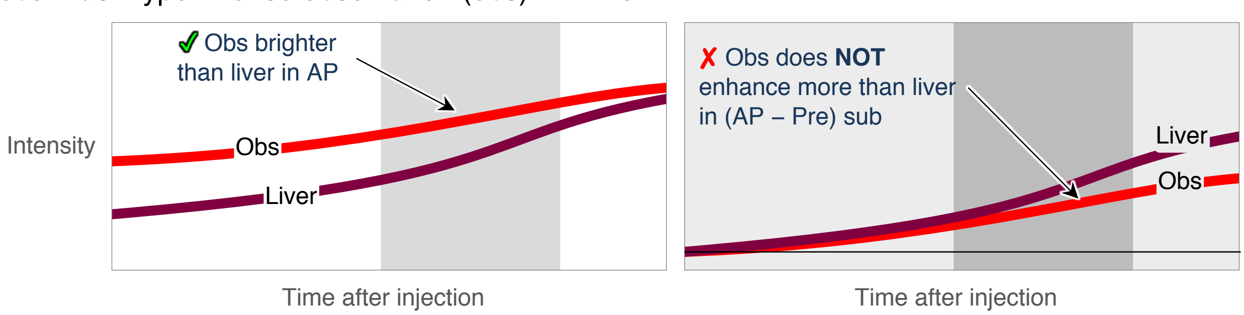
Time-Intensity Curves | **Baseline-Subtracted Time-Intensity Curves**



Precontrast hyperintense observation (obs) with APHE



Precontrast hyperintense observation (obs) with **No** APHE



Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Characterization (Cont'd)

The interpretation of APHE depends on whether early arterial, late arterial, or both early and late arterial phase images are acquired.

Although LI-RADS recommends late arterial phase imaging, this phase of the arterial phase is not always achievable. Hence, radiologists should determine in each exam what arterial phase(s) was acquired and characterize APHE accordingly.

The Table below summarizes the interpretation of APHE, depending on whether early arterial phase, late arterial phase, or both early and late arterial phase images are acquired.

Early Arterial Phase	Late Arterial Phase	Interpretation
APHE present	APHE present	APHE
APHE present	APHE not present	APHE
APHE present	Not acquired	APHE
APHE not present	APHE present	APHE
APHE not present	APHE not present	No APHE
APHE not present	Not acquired	Not able to characterize
Not acquired	APHE present	APHE
Not acquired	APHE not present	No APHE
Not acquired	Not acquired	Not able to characterize

Summary of rules in Table above:

- If APHE is detected in any arterial phase → characterize APHE as present
- If no arterial phase is acquired → APHE is noncharacterizable
- If no APHE is detected on early arterial phase images and late arterial phase is not acquired, APHE is noncharacterizable
- If no APHE is detected and and late arterial phase is acquired → characterize APHE as absent

Arterial Phase Hyperenhancement (APHE)

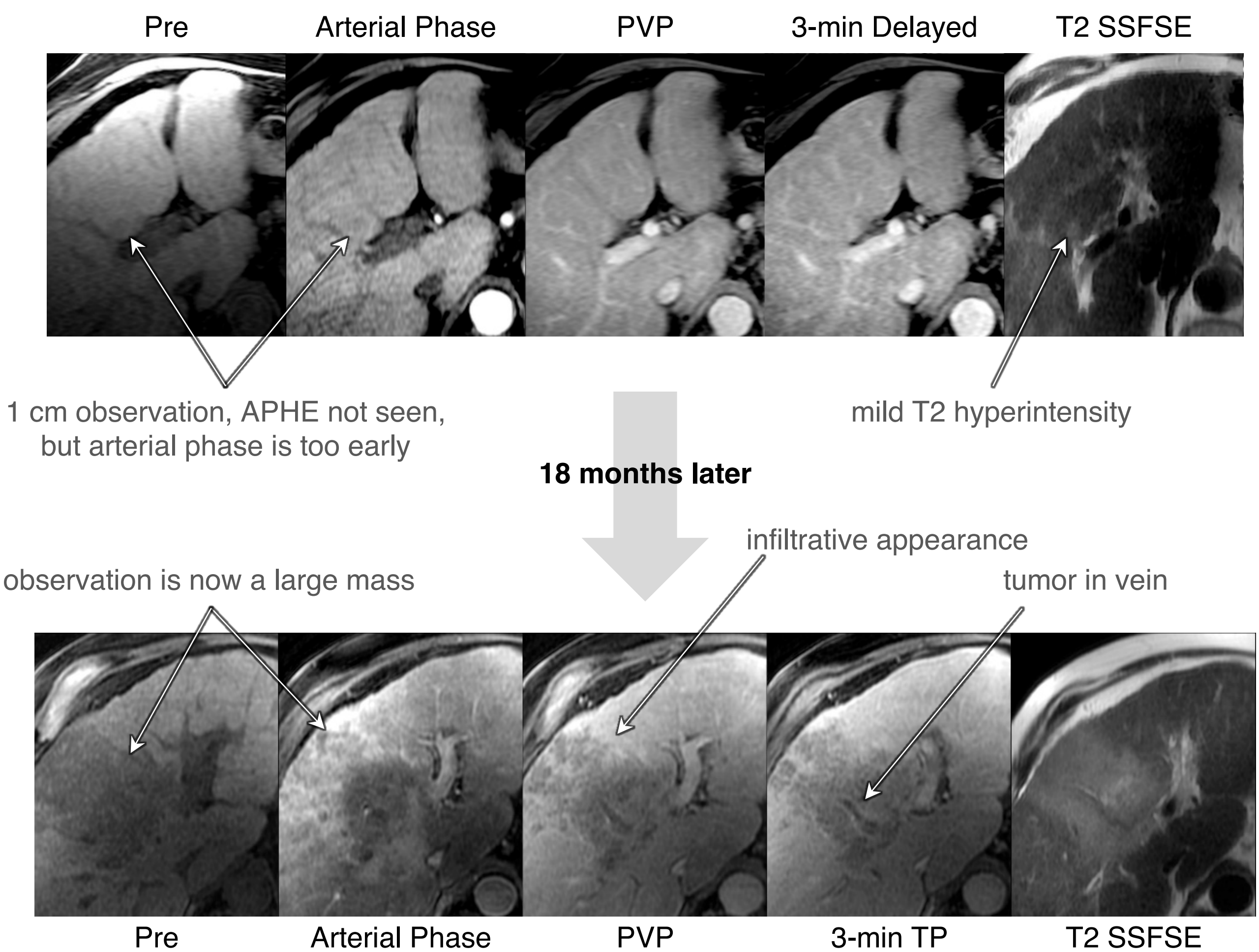
RADLEX ID: RID43355

Characterization (Cont’d)

Why it is important to recognize when APHE is noncharacterizable

MRI with extracellular contrast agent in 82-year-old man with compensated cirrhosis. There is a 1 cm observation in segment 4 (T1 hypointense, mildly T2 hyperintense). Arterial phase is too early, which makes APHE noncharacterizable. Observation was categorized LR-3.

MRI with extracellular agent



MRI with gadoxetate disodium

Patient was lost to follow up for 18 months. He returned with a large HCC with tumor in vein and infiltrative appearance, as seen on MRI with gadoxetate disodium. Recognition on first MRI that arterial phase was too early might have communicated a more urgent need for a repeat study, which could have increased chance of an earlier follow-up with potential to detect HCC sooner.

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

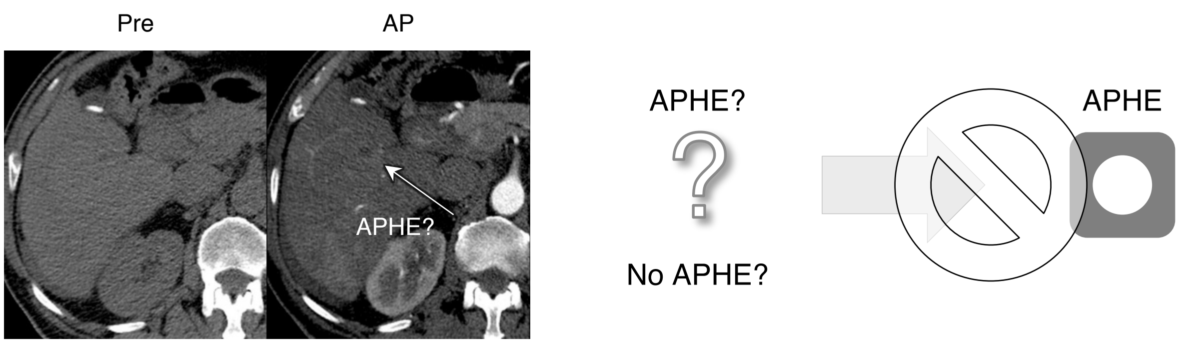
Characterization (Cont'd)

If unsure

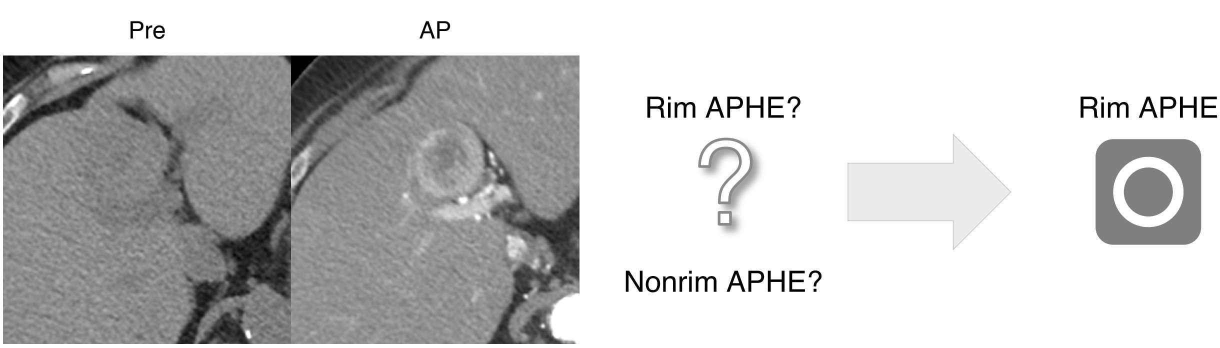
If unsure about APHE vs no APHE, characterize as no APHE
- *Rationale: LI-RADS imaging features are characterized as present only if there is certainty*

If unsure about rim APHE vs nonrim APHE, characterize as rim APHE
- *Rationale: provides low threshold for alerting referrer to possibility of non-HCC malignancy*

Example: APHE vs no APHE, characterize as no APHE



Example: rim APHE vs nonrim APHE, characterize as rim APHE



Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

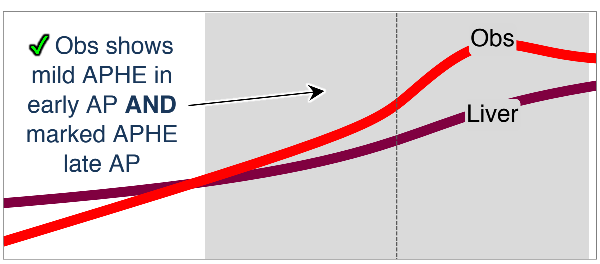
Pitfalls & practical considerations

APHE associated with HCC and other malignant neoplasms is usually seen more reliably on late AP than early AP images. Sometimes it is seen only on late AP images. For this reason, LI-RADS recommends that AP images be acquired in the late AP.

APHE seen MORE EASILY in late AP

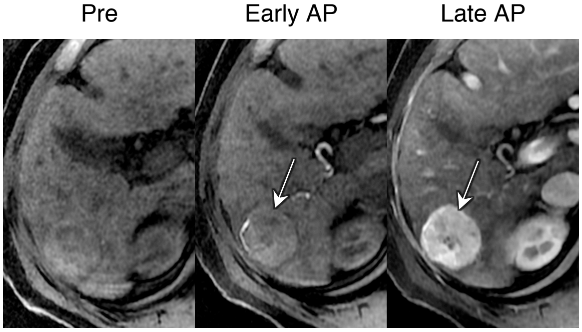
Pre | Early AP | Late AP

Arterial Phase



Early AP | Late AP

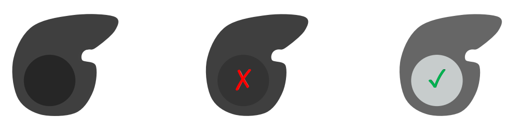
Pre | Early AP | Late AP



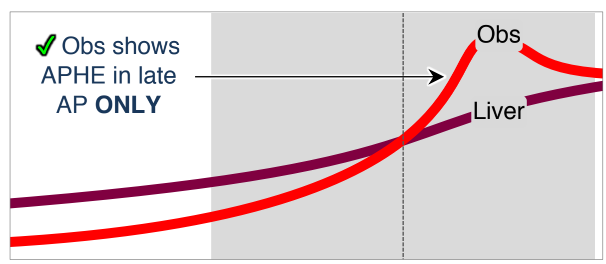
✓ APHE barely seen | ✓ APHE Seen easily

APHE seen ONLY in late AP

Pre | Early AP | Late AP

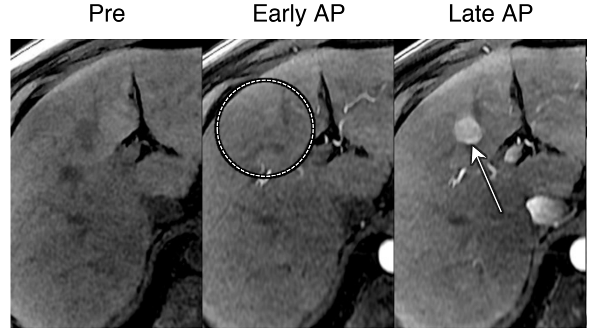


Arterial Phase



Early AP | Late AP

Pre | Early AP | Late AP



✗ APHE not seen | ✓ APHE seen

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Pitfalls & practical considerations (Cont'd)

Not all HCCs show APHE.

Absence of detectable APHE may reflect

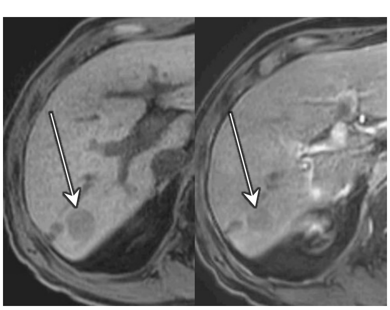
- Arterial phase mistiming
  - True APHE may be missed due to arterial phase mistiming. For example, the absence of detectable APHE on early AP images does not exclude the presence of APHE (see *page 16-32*).
- Incomplete neoarterialization
  - Usually seen in early, very well-differentiated HCCs.
- Conversion from aerobic to anaeorbic glycolysis due to insufficient perfusion.
  - Usually seen in poorly differentiated HCCs with infiltrative appearance.

Examples of HCCs without true APHE include:

- Early HCCs
- Very steatotic HCCs
- Poorly differentiated HCCs (pd HCC) with infiltrative appearance
- Some expansile, progressed (overtly malignant) HCCs

Early HCC

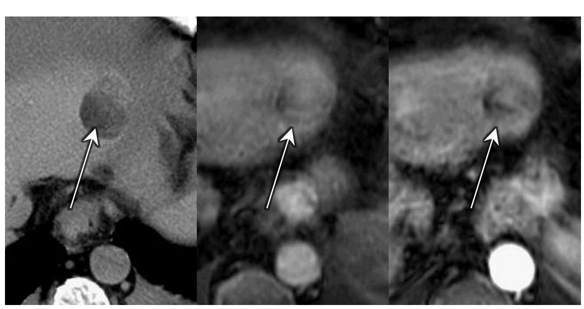
Pre AP



✗ **No APHE**

Steatotic HCC

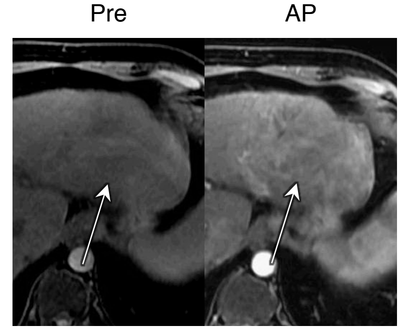
Non-contrast CT MRI: Pre MRI: AP



✗ **No APHE**

Poorly differentiated HCC

Pre AP



✗ **No APHE**

Hence, while APHE (nonrim APHE, in particular) is required for LR-5 categorization, the absence of APHE does not exclude HCC.

Arterial Phase Hyperenhancement (APHE)

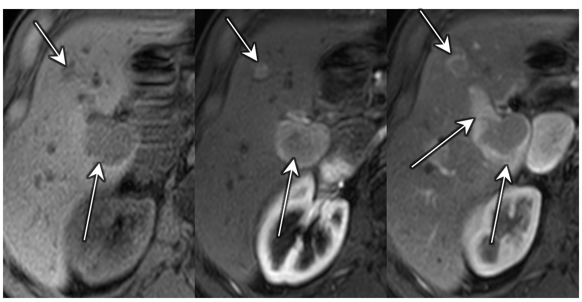
RADLEX ID: RID43355

Pitfalls & practical considerations (Cont'd)

Although APHE is usually most conspicuous in the late arterial phase, it is occasionally more conspicuous in the early arterial phase (i.e., earlier than expected) or in the nominal portal venous phase (i.e., later than expected), depending on exact timing of each phase, altered systemic, splanchnic and hepatic blood flow in cirrhosis, and tumor biology.

APHE more conspicuous in early AP

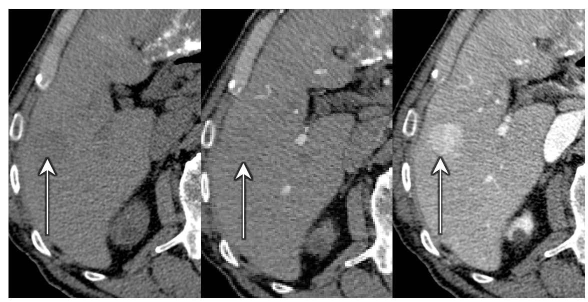
Pre | Early AP | Late AP



APHE | Corona, not APHE

APHE more conspicuous in nominal PVP

Pre | Nominal AP | Nominal PVP



APHE not yet seen | APHE seen

Since it is well established that APHE is usually more conspicuous in the late arterial phase than the early AP, it is assumed that the late AP is better than the early AP for differentiating rim APHE from nonrim APHE.

However, this assumption has not been proven in clinical studies.

As stated on *page 16-18*, APHE requires **BOTH** greater enhancement **AND** greater brightness than liver in the arterial phase.

Observations that are darker than liver precontrast and enhance to become isointense or isoattenuating in the arterial phase do not have APHE by definition, since they fail to meet the second requirement.

The requirement for greater brightness than liver, not just greater enhancement, is intended to reduce false-positive diagnoses of HCC.

It is based on expert opinion as the literature is unclear on this issue.

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

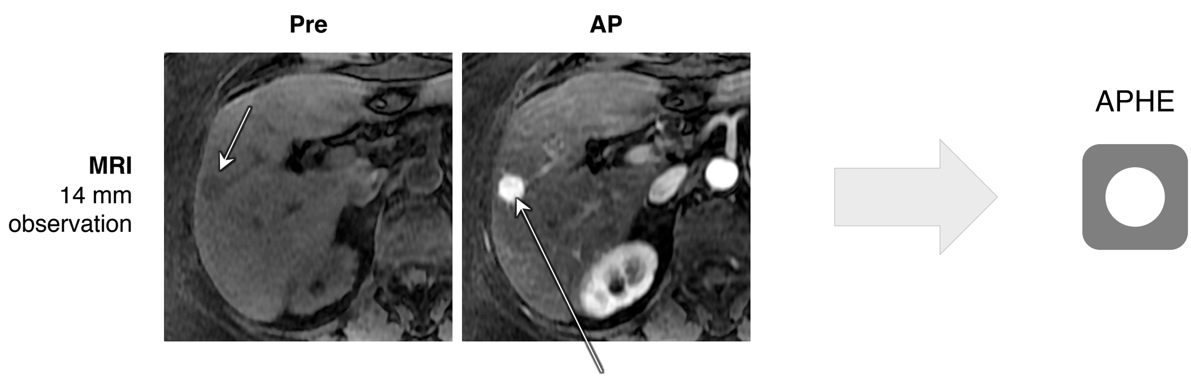
Pitfalls & practical considerations (Cont'd)

Compared with other MR agents, gadoxetate disodium is less likely to depict APHE due to lower gadolinium dose and higher frequency of respiratory motion-induced image degradation in the arterial phase. See *Chapter 13*.

Since lesions that are hypointense precontrast and isointense in the arterial phase may be HCC, consider reimaging with a different modality such as CEUS or multi-arterial phase MRI, both of which reduce the risk of arterial phase mistiming.

There is no minimum size for application of APHE, rather its presence should be unequivocal in judgment of the radiologist.

Do: Compare degree of enhancement and arterial-phase brightness relative to liver



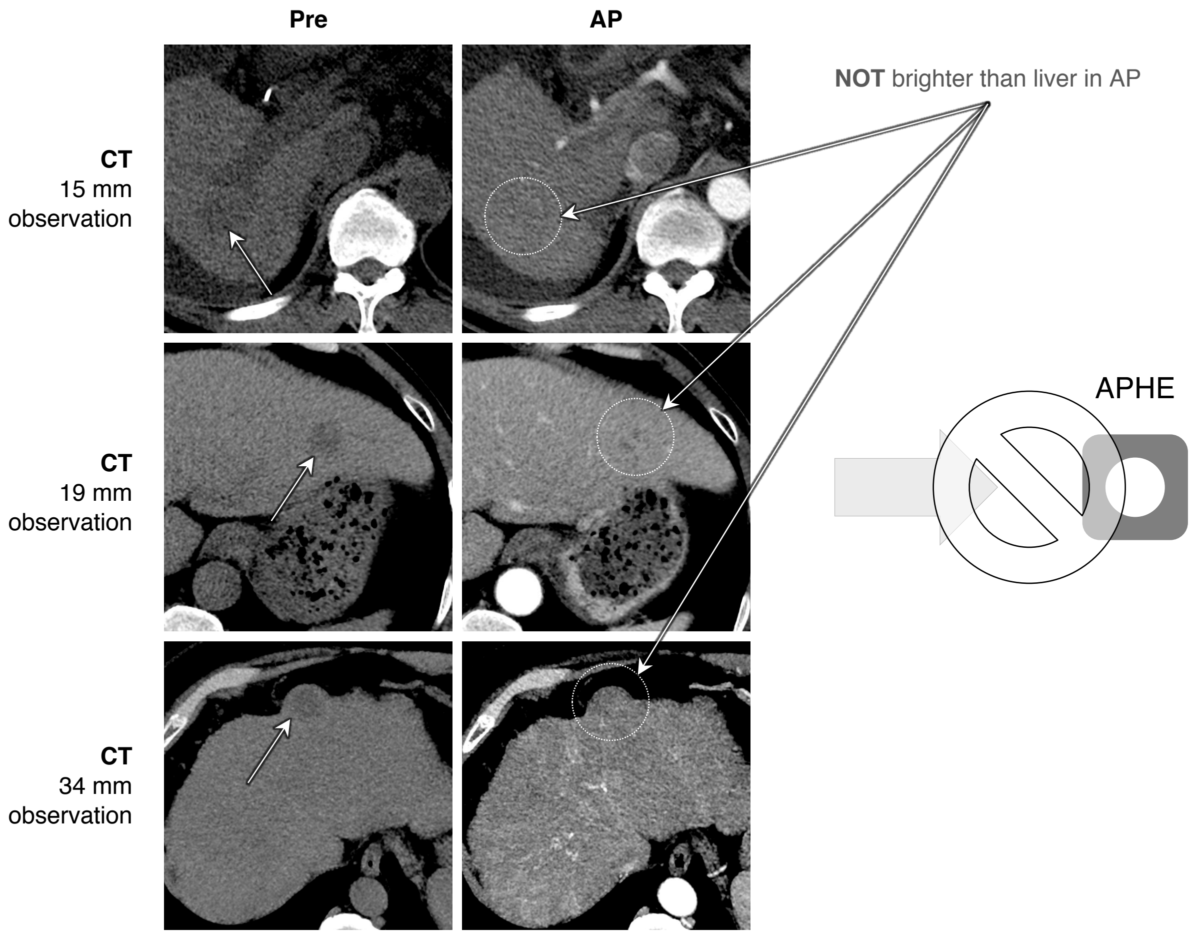
Enhances more than liver AND is brighter than liver in AP

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Pitfalls & practical considerations (Cont'd)

Do not: Characterize hypo (pre) → iso (AP) as APHE



May: With caution use subtractions at MRI if observation is intrinsically T1 hyperintense (make sure pre/post images are registered and have same calibration) (*page 16-26*)

Do: Include in your report if subtractions were necessary to characterize APHE.

May: Use subtractions with caution to characterize APHE when pre/AP images are misregistered if degree of spatial misregistration is small relative to regions(s) being assessed for enhancement.

⚠ **Caution**: Do not use subtractions to characterize APHE if observation is hypointense or isointense compared to liver precontrast

Arterial Phase Hyperenhancement (APHE)

RADLEX ID: RID43355

Pitfalls & practical considerations (Cont'd)

Other pitfalls and practical considerations related to rim APHE, nonrim APHE and nodular discontinuous APHE are discussed in subsequent sections.

References

For rim APHE: see *page 16-60*.

For nonrim APHE: see *page 16-81*.

Rim APHE

RADLEX ID: N/A

Definition

Spatially defined subtype of APHE in which APHE is most pronounced in periphery of observation. Rim of enhancement in the arterial phase must be continuous but need not be complete. It may be so smooth or irregular.

Synonyms

Peripheral APHE, ring APHE, targetoid APHE, APHE in target pattern, rim enhancement

---

Terminology

The term rim APHE is preferred as it is clear, unambiguous, and commonly used in the radiology literature.

Applicable methods

CT, MRI

Type of feature

Targetoid LR-M feature

Effect on categorization

Rim APHE is sufficient for LR-M. See *page 16-9*.

By itself, it is enough for LR-M.

Thus, all untreated observations with rim APHE are LR-M, regardless of other imaging features.

- Exceptions:
  - If there is tumor in vein, categorize as LR-TIV.
  - If observation is path proven, report path diagnosis, not LI-RADS category.
  - If observation is an abscess, categorize as LR-1 or LR-2 depending on confidence level

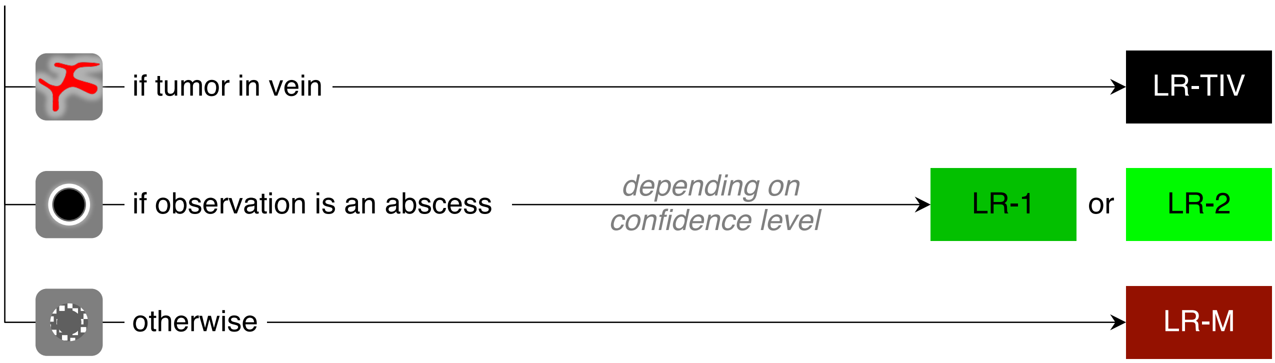
Rim APHE

RADLEX ID: N/A

Effect on categorization (Cont'd)

Rim APHE is sufficient for LR-M. See *page 16-9*.

Nonpath-proven observation with rim APHE



Rim APHE is not required for LR-M. See *page 16-9*.

Observations without rim APHE can be LR-M if other LR-M features are present.

- Example: Observation with peripheral "washout" and HBP targetoid pattern but not rim APHE.

Biological basis

Rim APHE reflects neovascularity concentrated mainly in the tumor periphery. It frequently occurs in conjunction with relatively reduced central perfusion, which can lead to central fibrosis, ischemia, and/or necrosis.

This spatial subtype of APHE is characteristic of iCCA and other non-HCC malignancies. It is not characteristic of HCC, which tends to have neovascularity that is diffuse rather than concentrated in the tumor periphery.

Peripheral "washout" is a manifestation of targetoid appearance, a constellation of LR-M features with similar biological basis and often co-existing in the same observation. This family includes rim APHE, peripheral "washout", delayed central enhancement, targetoid restriction, and targetoid appearance in TP and/or HBP images. See *page 16-205*.

Rim APHE

RADLEX ID: N/A

Summary of evidence

In single-center retrospective studies, rim APHE was seen in

- 50-84% of iCCA
- 54% of cHCC-CCAs
- 14-17% of HCCs.

Most of these studies were in mixed populations including patients without underlying chronic liver disease, limiting their generalizability to the LI-RADS diagnostic target population.

Note that rim APHE does not exclude HCC (see Pitfalls, page 16-47).

Rim APHE occurs in association with other targetoid LR-M features since it is thought to reflect the same underlying pathology: peripheral arterialization and hypercellularity in conjunction with central fibrosis and ischemia. The frequency and diagnostic accuracy of rim APHE in the absence of other targetoid LR-M features is unknown.

Rim APHE

RADLEX ID: N/A

Characterization

See page 16-18 for general concepts about APHE and page 16-26 for use of subtractions.

Characterize rim APHE on arterial phase images. Late arterial phase images are thought to be more reliable for characterizing any type of APHE, including rim APHE, than early arterial phase images (see page 16-32), but the ability of late vs. early AP images to detect rim APHE in particular and to differentiate rim APHE from nonrim APHE has not been compared in research studies.

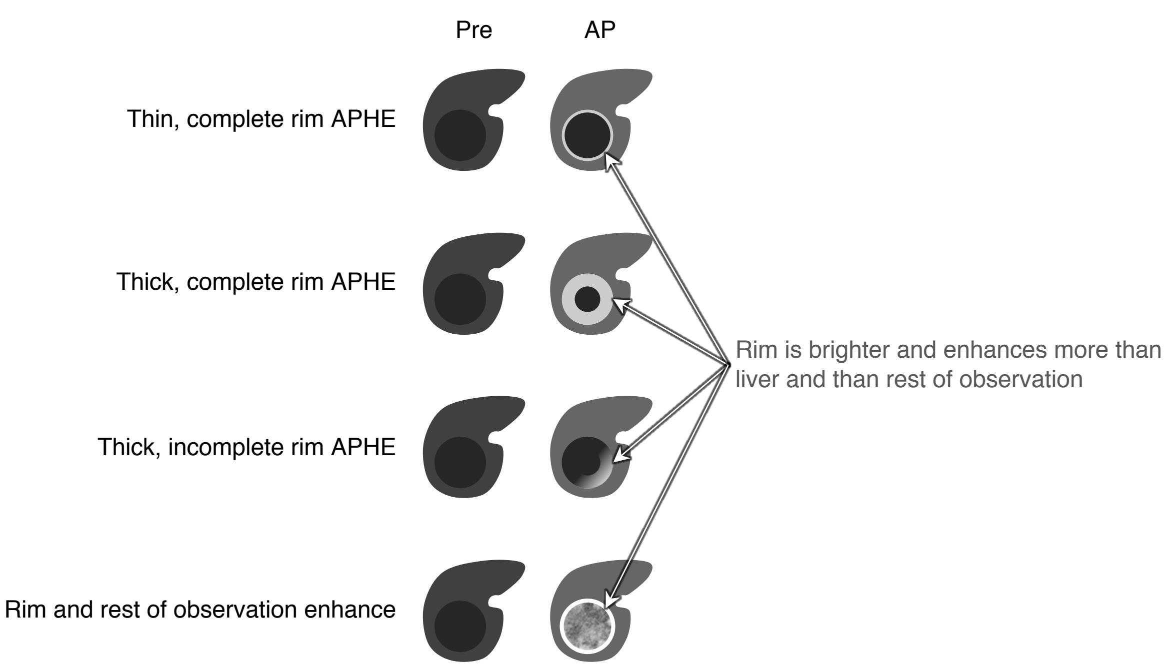
Rim APHE is present if in the arterial phase **BOTH** of the following are met:

- The observation rim enhances more and is brighter than liver AND
- The observation rim enhances more and is brighter than rest of observation

The enhancement of the rim is continuous, unlike the discontinuous nodular enhancement characteristic of a hemangioma, but need not be complete.

The rest of the observation may enhance in the arterial phase but the degree of is less than the rim.

The rim APHE may be thin or thick, smooth or irregular.



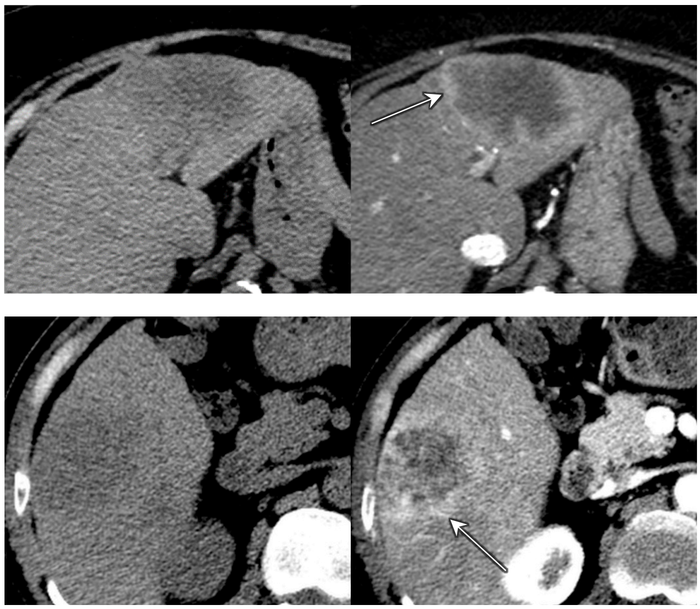
Rim APHE

RADLEX ID: N/A

Characterization (Cont'd)

Examples: CT

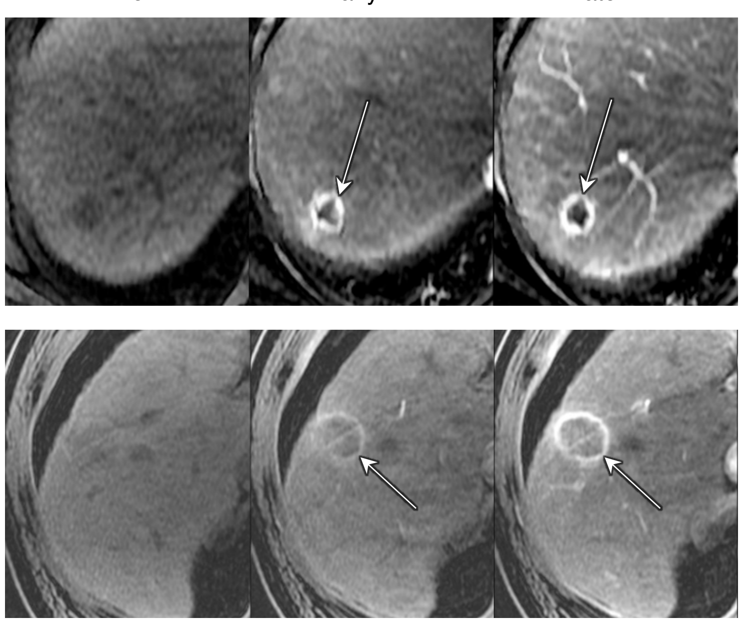
Pre AP



Peripheral rim of arterial hyperenhancement

Examples: MRI

Pre Early AP Late AP



Peripheral rim of arterial hyperenhancement

Rim APHE

RADLEX ID: N/A

Characterization (Cont'd)

If unsure

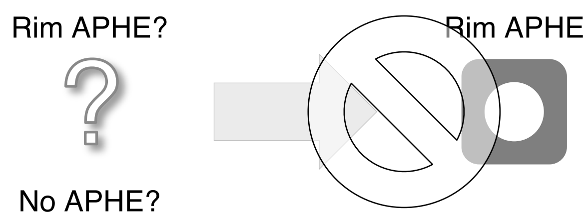
If unsure about rim APHE vs no APHE, characterize as no APHE

- *Rationale: LI-RADS imaging features are characterized as present only if there is certainty*

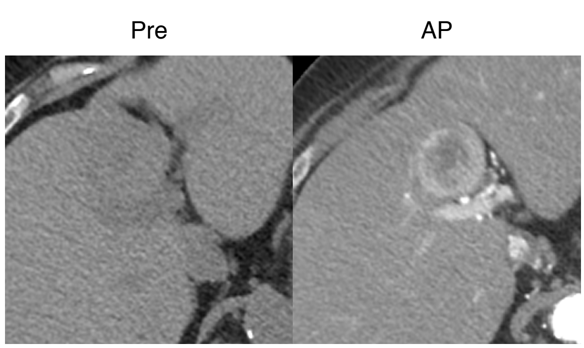
If unsure about rim APHE vs nonrim APHE, characterize as rim APHE

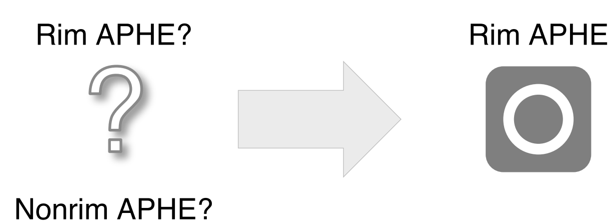
- *Rationale: provides low threshold for alerting referrer to possibility of non-HCC malignancy*

Example: rim APHE vs no APHE, characterize as no APHE



Example: rim APHE vs nonrim APHE, characterize as rim APHE





Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations

See page 16-32 for general APHE pitfalls & practical considerations.

Small iCCA (< 3 cm) may have nonrim APHE, complicating their differentiation from HCC.

Example: path-proven iCCA with nonrim APHE, 61-yo man with chronic HBV

Pre | AP

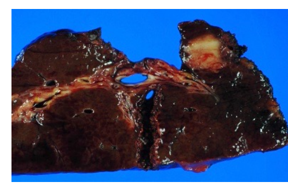
CT
16 mm

MRI
16 mm
(same patient
as above)

Diffuse APHE. **NOT** rim APHE

Resection

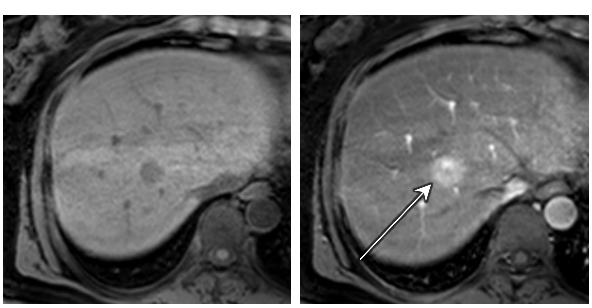
iCCA



Example: path-proven iCCA with nonrim APHE, 67-yo man with chronic HBV

Pre | AP

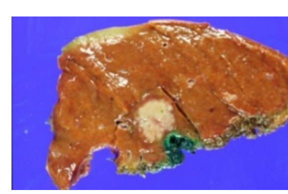
MRI
18 mm



Diffuse APHE, **NOT** rim APHE

Resection

iCCA



Small iCCAs may be indistinguishable from HCCs in the arterial phase, with both types of malignant neoplasms having nonrim APHE

Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Small iCCA (< 3 cm) may have an atypical appearance, having nonrim APHE rather than rim APHE, complicating their differentiation from HCC.

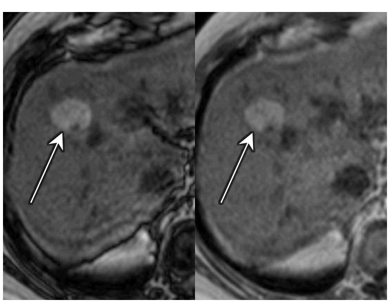
Clues to differentiation for small masses with nonrim APHE thought to be malignant

- Favoring HCC (if present): T1 hyperintensity, fat in mass, “capsule” (enhancing and/or nonenhancing). *Observations with any of these features usually should be categorized LR-3, LR-4, or LR-5.*
- Favoring iCCA (if present): other targetoid LR-M features (delayed central enhancement, peripheral WO, targetoid appearance (DWI, transitional phase, HBP). *Observations with any of these features usually must be categorized LR-M.*

Small mass with nonrim APHE thought to be malignant: favoring HCC

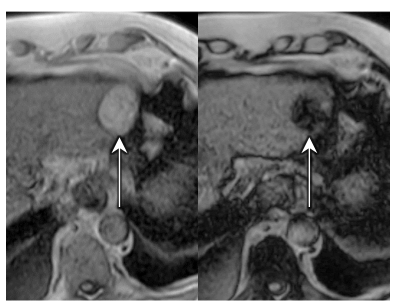
T1 hyperintensity

T1w OP | T1w IP



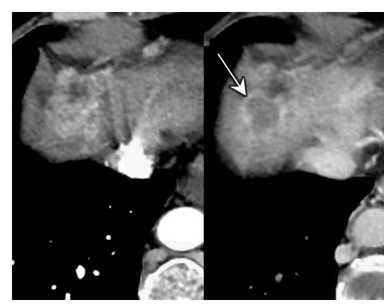
Fat in mass

T1w OP | T1w IP



“Capsule”

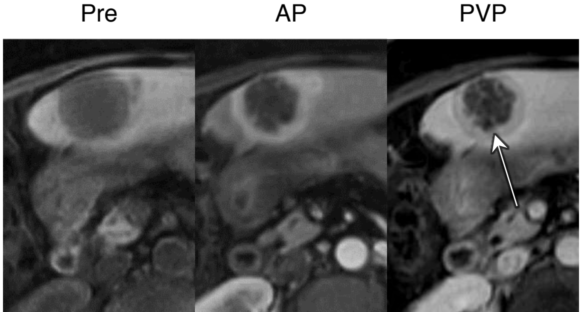
AP | DP



Small mass with nonrim APHE thought to be malignant: favoring iCCA

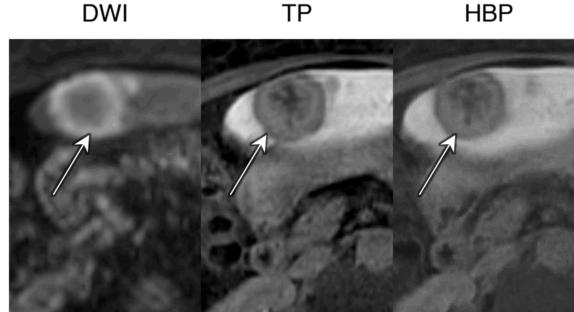
Delayed central enhancement and/or peripheral WO

Pre | AP | PVP



Targetoid appearance

DWI | TP | HBP

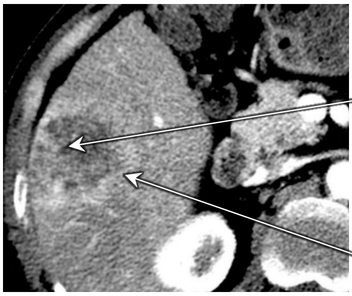


Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Observations with rim APHE may have areas of internal enhancement as well as peripheral enhancement. These areas do not enhance as much as the rim.



Note internal areas of enhancement. These do not enhance as much as the rim

Rim APHE

Some observations other than iCCAs and cHCC-CCAs may have rim APHE:

- HCCs with any of the following characteristics
    - steatosis (e.g., steatohepatitic HCC)
    - blood products (e.g., hemorrhagic HCC)
    - fibrosis (e.g., scirrhous HCC)
    - necrosis (e.g., poorly differentiated HCC)
- Sclerosing hemangiomas
- Abscesses and other inflammatory lesions
- Necrotic HCCs
- Treated observations
- Ringlike perfusion alterations

The above pitfalls are discussed and illustrated in the pages that follow.

Rim APHE

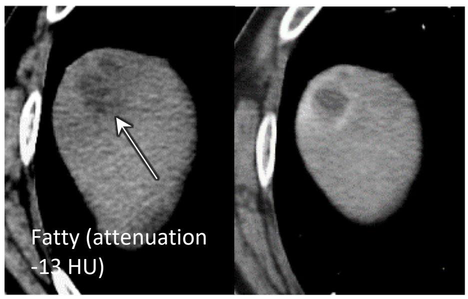
RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

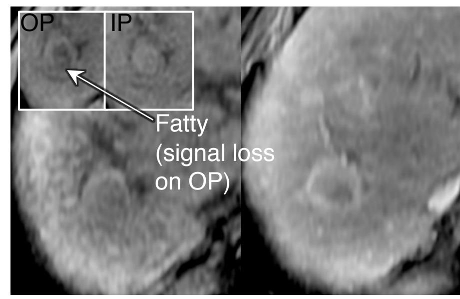
HCCs with any of the following characteristics may have rim APHE:

- steatosis (steato-hepatitic HCC)

Pre AP

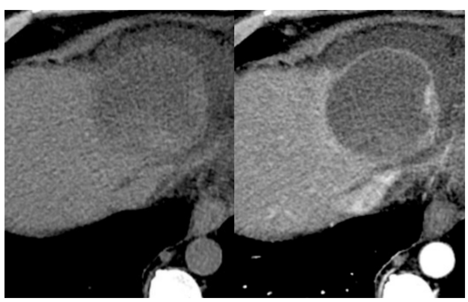


Pre AP

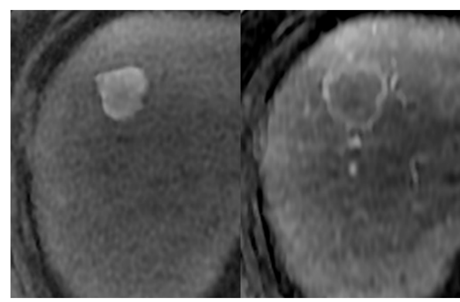


- blood products (hemorrhagic HCC)

Pre AP

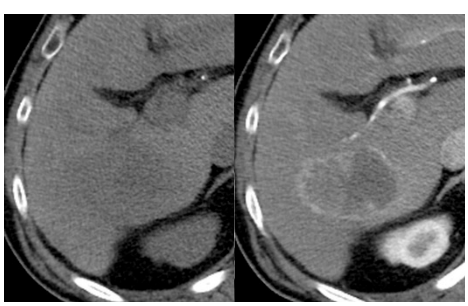


Pre AP

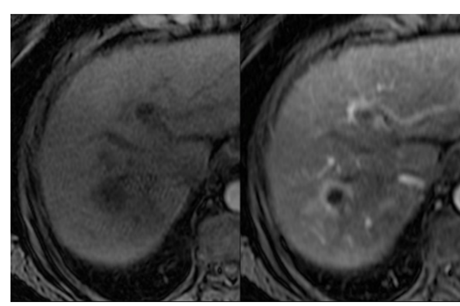


- necrosis (poorly differentiated HCC)

Pre AP

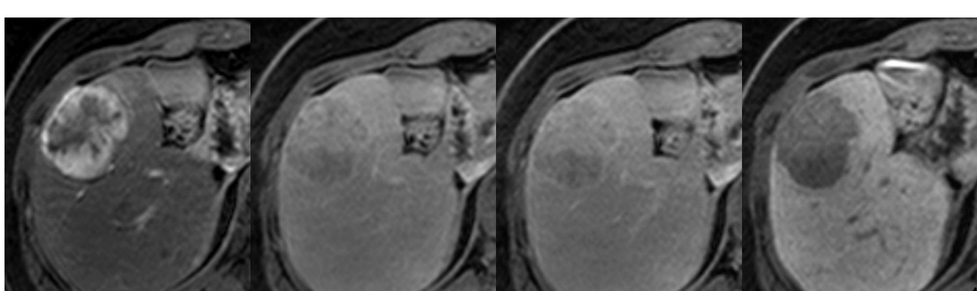


Pre AP



- fibrosis (scirrhous HCC)

AP PVP TP HBP



Rim APHE

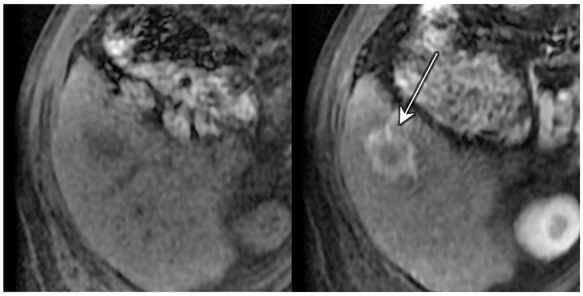
RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Metastases, sarcomas and lymphomas may have rim APHE

- Metastasis

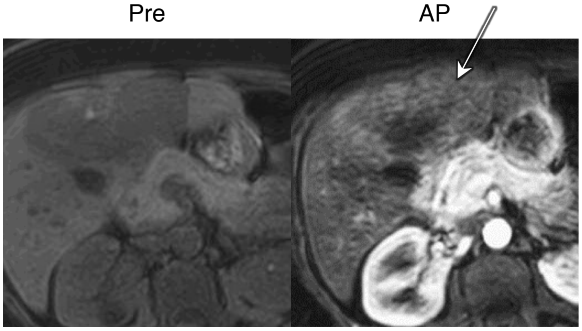
Pre AP



Colon metastasis

- Sarcoma

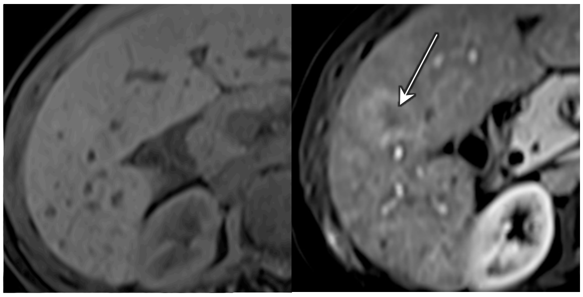
Pre AP



Spindle cell sarcoma

- Lymphoma

Pre AP



Non-Hodgkin lymphoma

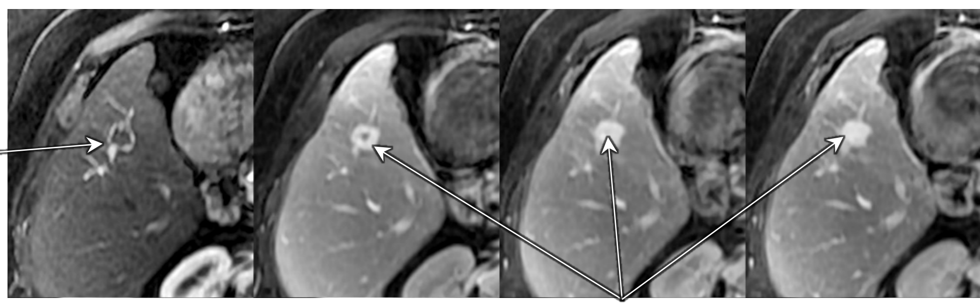
Rim APHE

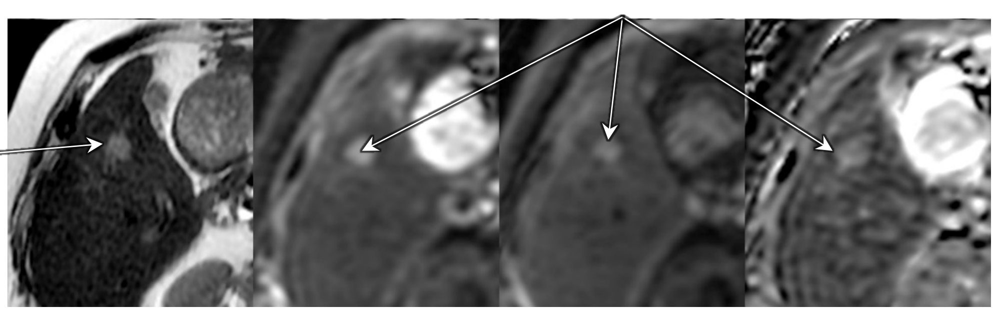
RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Sclerosing hemangiomas may have rim APHE

- Hemangiomas in the cirrhotic liver tend to fibrose (sclerosing hemangiomas) and may have unusual imaging such as continuous peripheral rim enhancement. This may cause diagnostic confusion and prompt LR-M categorization.
- 💡 In such cases, recognizing other features of hemangioma may permit LR-1 or LR-2 categorization, depending on confidence level. See figure below.





💡 If available, comparison to old studies may help: sclerosing hemangiomas tend to involute and become smaller over time while malignant lesions tend to grow.

See Hemangiomas, *Chapter15, page 4* for more information.

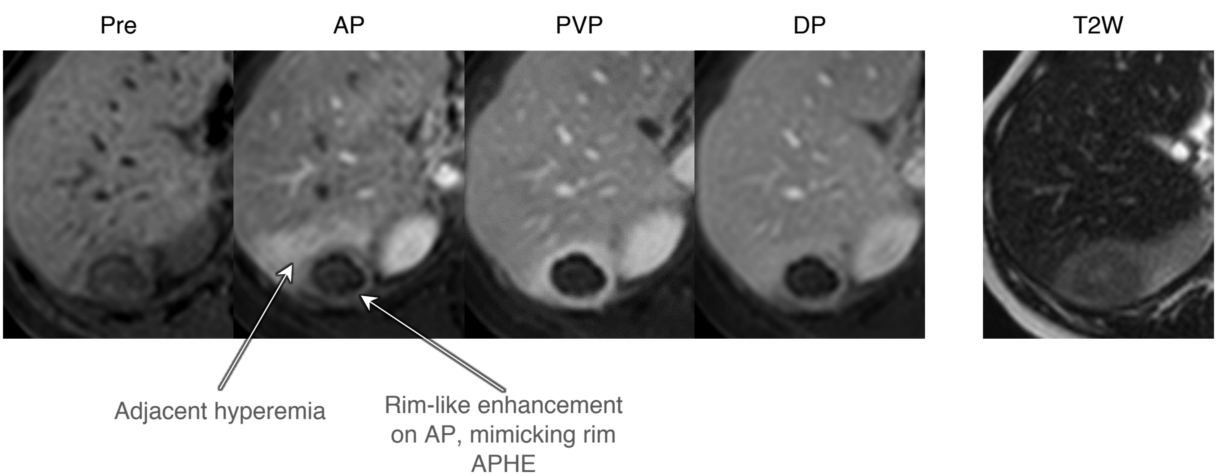
Rim APHE

RADLEX ID: N/A

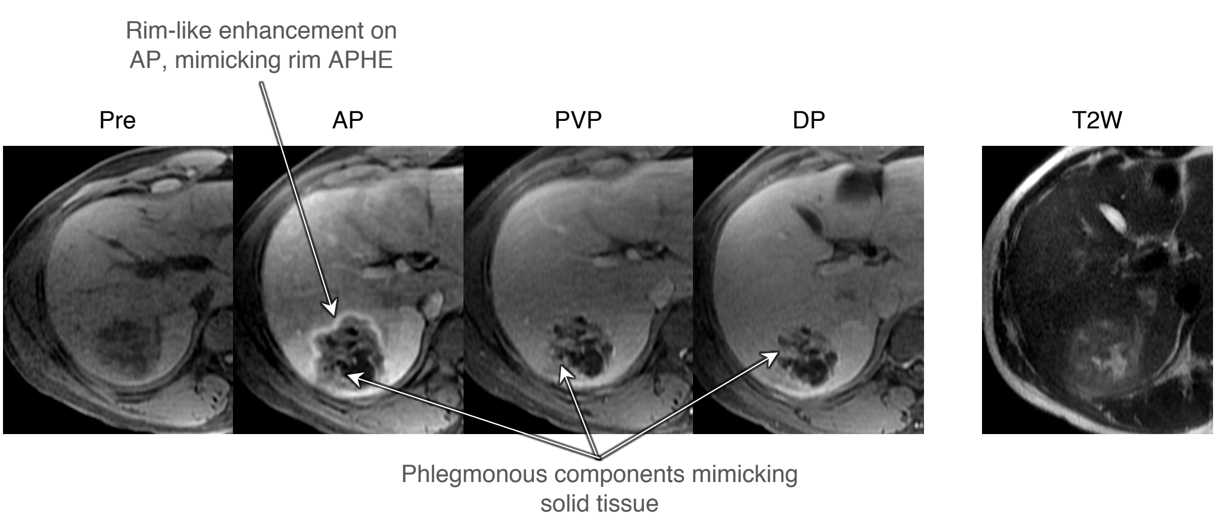
Pitfalls & practical considerations (Cont'd)

Abscesses and other inflammatory lesions may have rim APHE.

- These typically have thin enhancing walls, septations of variable thickness, but no solid nodules. Internal contents do not enhance and usually are markedly T2 hyperintense.



- Rarely, an abscess may have solid-appearing phlegmonous components. Thus, imaging-based differentiation from abscess can be difficult.



Rim APHE

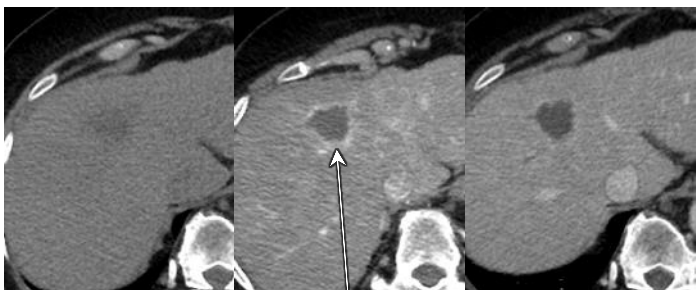
RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Treated observations may have rim APHE.

Example: CT

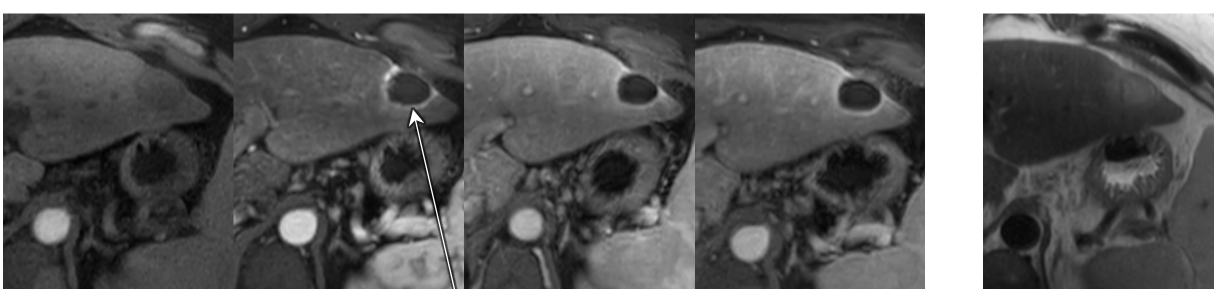
Pre AP PVP



Thin rim of peripheral enhancement on AP surrounding an observation is an expected post-TACE finding but may mimic rim APHE

Example: MRI

Pre AP PVP DP T2W



Thin rim of peripheral enhancement on AP surrounding an observation is an expected post-TACE finding but may mimic rim APHE

Rim APHE is expected finding after many locoregional therapies (*Chapter 9*)

Do not misinterpret posttreatment rim enhancement as a feature of LR-M.

Rim APHE

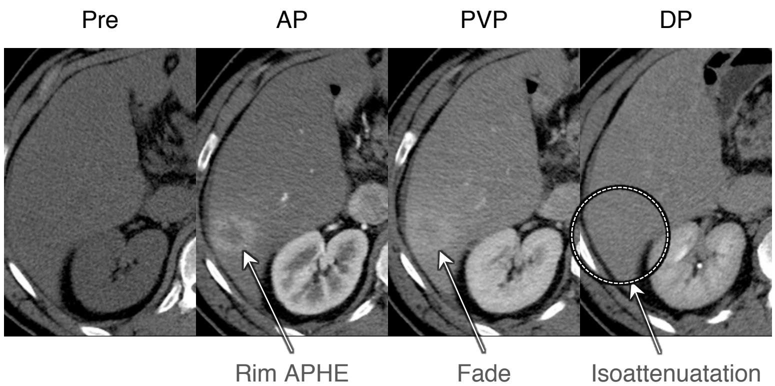
RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

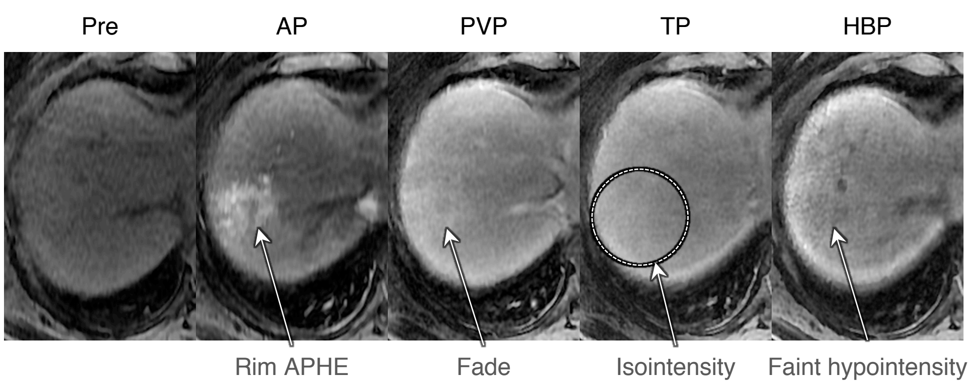
Perfusion alterations may have rim APHE.

- Rarely, a perfusion alteration may have a rim configuration and be mistaken for a mass

Example: CT

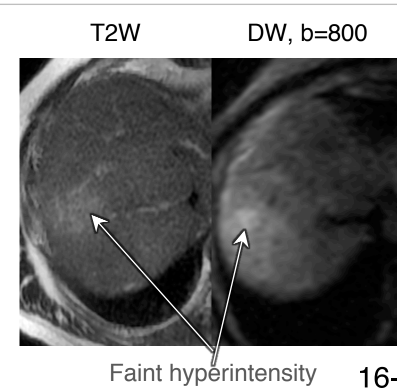


Example: MRI



For observations with rim APHE, features that suggest perfusion alteration rather a true mass include

- isoattenuation or isointensity on precontrast and postarterial extracellular phase images
- isointensity or faint hyperintensity on T2W and DW images
- isointensity or faint hypointensity on HBP images
- undistorted vessels



Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Some enhancement patterns may mimic rim APHE:

- Peripheral discontinuous nodular enhancement of hemangiomas
- Corona enhancement
- Enhancing “capsule”

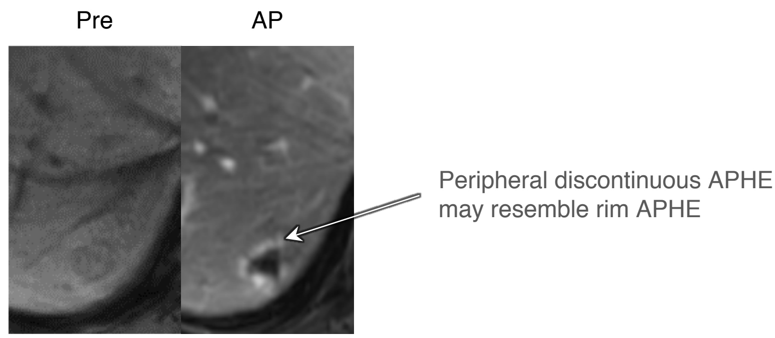
The above pitfalls are discussed and illustrated in the pages that follow.

Rim APHE

RADLEX ID: N/A

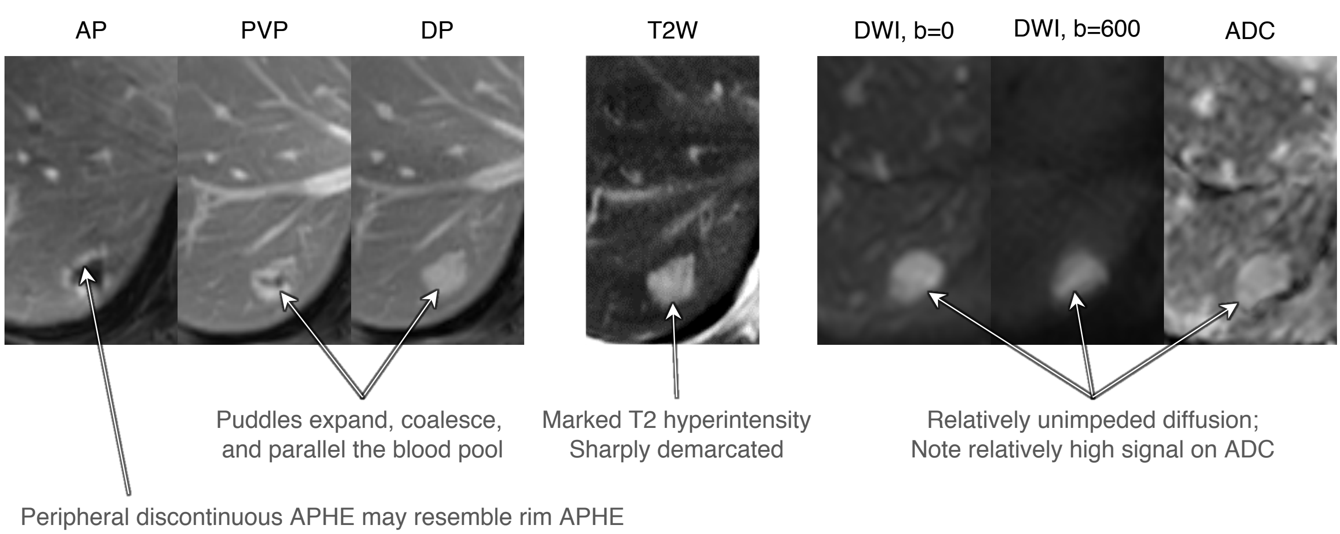
Pitfalls & practical considerations (Cont'd)

The peripheral discontinuous nodular enhancement of hemangiomas may resemble rim APHE.



- If unsure about rim APHE vs. nodular discontinuous APHE, look for other features of hemangioma (e.g. enlarging "puddles" of enhancement paralleling blood pool, marked T2 hyperintensity, relatively unimpeded diffusion).

Same patient as above



- If still unsure, categorize as LR-3.
  - *Rationale: avoid categorizing atypical hemangiomas as LR-M*

Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Corona enhancement (see page 16-265) may resemble rim APHE.

- Corona enhancement is a transient zone of perilesional enhancement thought to represent the venous drainage area of malignant tumors such as HCC.
- It may involve the tumor “capsule” (if present) as well as the peri-tumoral parenchyma.
- The corona around the tumor may resemble rim APHE if images are acquired at a a time point in which the observation has “washed out” but the corona enhancement is still present.
- The distinction between rim APHE and corona can be difficult.

- Distinction (see examples on the next page):
  - Corona enhancement occurs in the liver parenchyma, not the lesion itself, whereas rim enhancement is part of the lesion.
  - Corona enhancement tends to blend into the surrounding liver, whereas true rim enhancement is more distinct.
  - Being a flow phenomenon, the corona enhancement area usually is occult on unenhanced images, whereas being part of the tumor, the enhancing rim may be visible on other images.

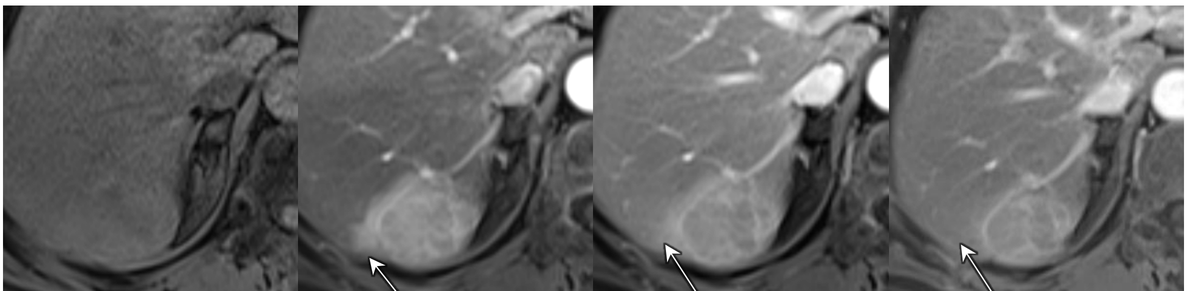
Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Pre | AP | PVP | DP

Corona

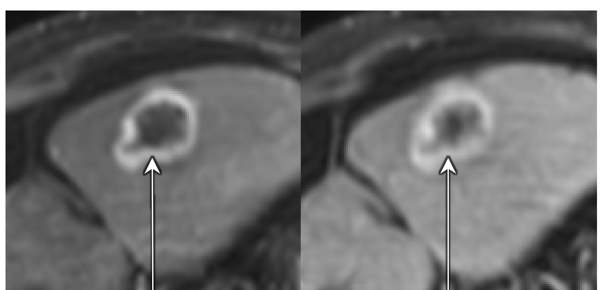


Enhancement in the adjacent parenchyma

Enhancement blends with adjacent liver

Transient phenomenon

Rim APHE



Enhancement on the edge of the observation, not in adjacent liver

Enhancement is distinct from adjacent liver, does not blend into it

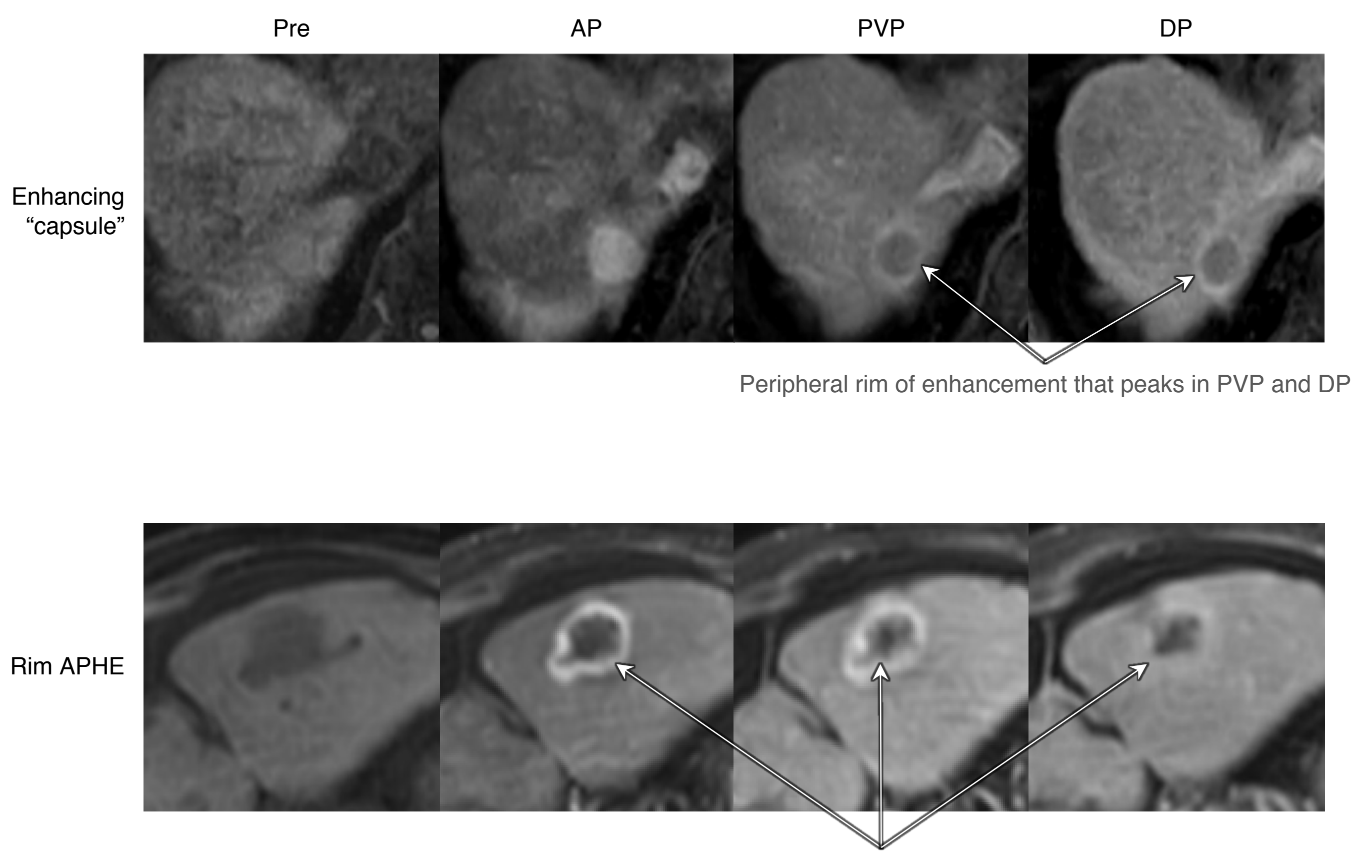
Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Enhancing “capsule” (see *page 16-187*) may resemble rim APHE.

- Distinction:
  - “Capsule” enhancement usually begins *after* the arterial phase and peaks in the PVP, DP, or TP, whereas by rim APHE usually peaks in the arterial phase and then appears to wash out on postarterial phases (peripheral “washout”).
  - “Capsule” is smooth, well defined, and uniform, whereas rim APHE may be thick, irregular and less sharply defined.



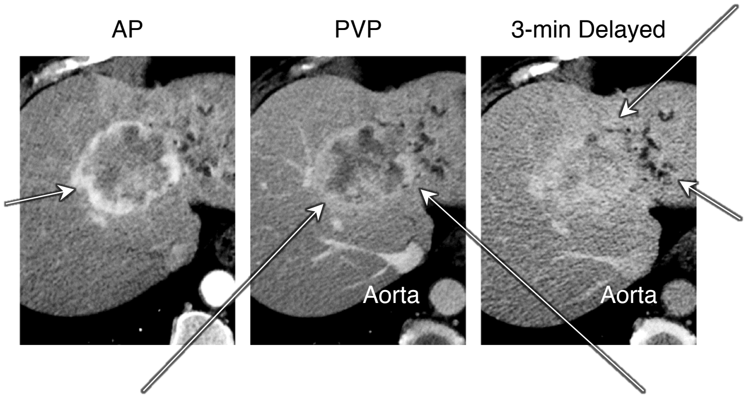
Rim APHE

RADLEX ID: N/A

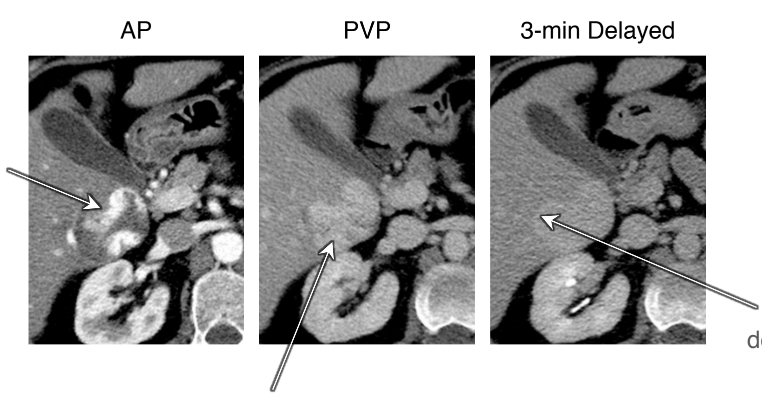
Pitfalls & practical considerations (Cont'd)

The peripheral rim of a malignant neoplasm may be irregular and/or incomplete. If so, the rim APHE may be mistaken for the peripeheral discontinuous nodular enhancement of hemangioma. Whether complete or incomplete, rim APHE should not be confused with the peripheral discontinuous nodular enhancement characteristic of classic hemangiomas.

Cholangiocarcinoma with irregular incomplete rim APHE



Hemangioma with peripheral discontinuous enhancement



Rim APHE

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Although late arterial phase images are thought to be more reliable for characterizing any type of APHE, including rim APHE, than early arterial phase images (see page 16-32), the ability of late vs. early AP images to detect rim APHE in particular and to differentiate rim APHE from nonrim APHE has not been compared in research studies.

Compared with other MR agents, gadoxetate disodium is less likely to depict nonrim APHE.

Subtractions are sometimes useful for characterizing rim APHE. See page 16-26 for discussion of subtractions.

There is no minimum size for application of rim APHE. As stated before rim APHE need not be complete. However, its presence should be unequivocal in judgment of radiologist.

Rim APHE

RADLEX ID: N/A

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Jeong HT, Kim MJ, Chung YE, Choi JY, Park YN, Kim KW. Gadoxetate disodium-enhanced MRI of mass-forming intrahepatic cholangiocarcinoma: imaging-histologic correlation. AJR. 2013; 201(4):W603-11.

Rim APHE

RADLEX ID: N/A

References (Cont'd)

Kim SH, Lee CH, Kim BH, et al. Typical and atypical imaging findings of intrahepatic cholangiocarcinoma using gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid-enhanced magnetic resonance imaging. J Comput Assist Tomogr. 2012;36(6):704-9.

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Mamone G, Marrone G, Caruso S, Carollo V, Gentile G, Crino F, Milazzo M, Luca A. Intrahepatic mass-forming cholangiocarcinoma: enhancement pattern on Gd-BOPTA-MRI with emphasis onhepatobiliary phase. Abdom Imaging. 2015; 40(7):2313-22.

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Potretzke TA, Tan BR, Doyle MB, Brunt EM, Heiken JP, Fowler KJ. Imaging Features of Biphenotypic Primary Liver Carcinoma (Hepatocholangiocarcinoma) and the Potential to Mimic Hepatocellular Carcinoma: LI-RADS Analysis of CT and MRI Features in 61 Cases. AJR Am J Roentgenol. 2016 Jul;207(1):25-31

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Wells ML, Venkatesh SK, Chandan VS, et al. Biphenotypic hepatic tumors: imaging findings and review of literature. Abdom Imaging. 2015;40(7):2293-305.

Rim APHE

RADLEX ID: N/A

References (Cont'd)

Kim SH, Lee CH, Kim BH, et al. Typical and atypical imaging findings of intrahepatic cholangiocarcinoma using gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid-enhanced magnetic resonance imaging. J Comput Assist Tomogr. 2012;36(6):704-9.

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Nishie A, Yoshimitsu K, Asayama Y, et al. Detection of combined hepatocellular and cholangiocarcinomas on enhanced CT: comparison with histologic findings. AJR. 2005;184(4):1157-62.

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Wells ML, Venkatesh SK, Chandan VS, et al. Biphenotypic hepatic tumors: imaging findings and review of literature. Abdom Imaging. 2015;40(7):2293-305.

Rim APHE

RADLEX ID: N/A

References (Cont'd)

Zhao YJ, Chen WX, Wu DS, Zhang WY, Zheng LR. Differentiation of mass-forming intrahepatic cholangiocarcinoma from poorly differentiated hepatocellular carcinoma: based on the multivariate analysis of contrast-enhanced computed tomography findings. Abdom Radiol (NY). 2016 May;41(5):978-89.

Peripheral Discontinuous Nodular Enhancement

RADLEX ID: RID43319

Characterization

Characterize on two or more contrast-enhanced phases of images. More than one phase is needed to verify the characteristic temporal pattern.

Peripheral nodular enhancement is present if ALL of the following:

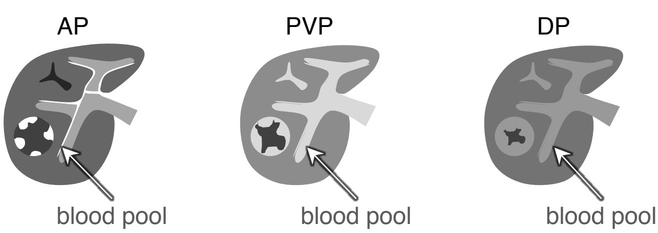
- There are peripheral nodular areas of enhancement **AND**
- The areas of enhancement expand on postarterial phases **AND**
- The areas of enhancement approximately parallel the blood pool in brightness on all phases

Radiologists should use their judgement in selecting the appropriate vessel(s) that represent the blood pool in each phase.

Depending on the phase, the duration of the contrast bolus, the exact timing of imaging relative to the end of the bolus, the presence of flow-related artifacts, and other factors, appropriate vessel(s) may include the aorta, portal vein(s), hepatic vein(s), or IVC.

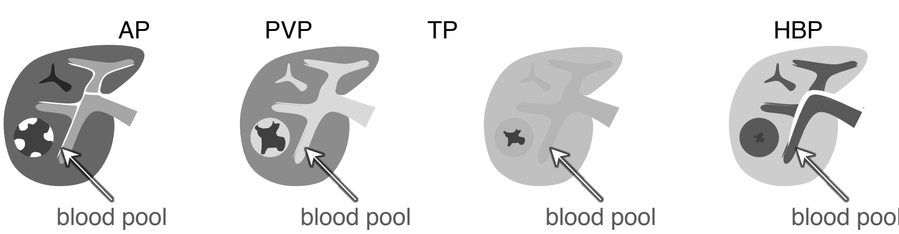
Peripheral discontinuous nodular enhancement: the “nodules” of enhancement should expand and parallel the blood pool.

Extracellular agent or gadobenate



With ECA, the blood pool remains brighter than liver, so the enhancing areas of the hemangioma remain brighter, too.

Gadoxetate



With gadoxetate disodium, the blood pool becomes darker than liver, so the enhancing areas of the hemangioma become darker, too

As the nodular areas of enhancement expand on postarterial phase images, they approximately parallel the blood pool in brightness.

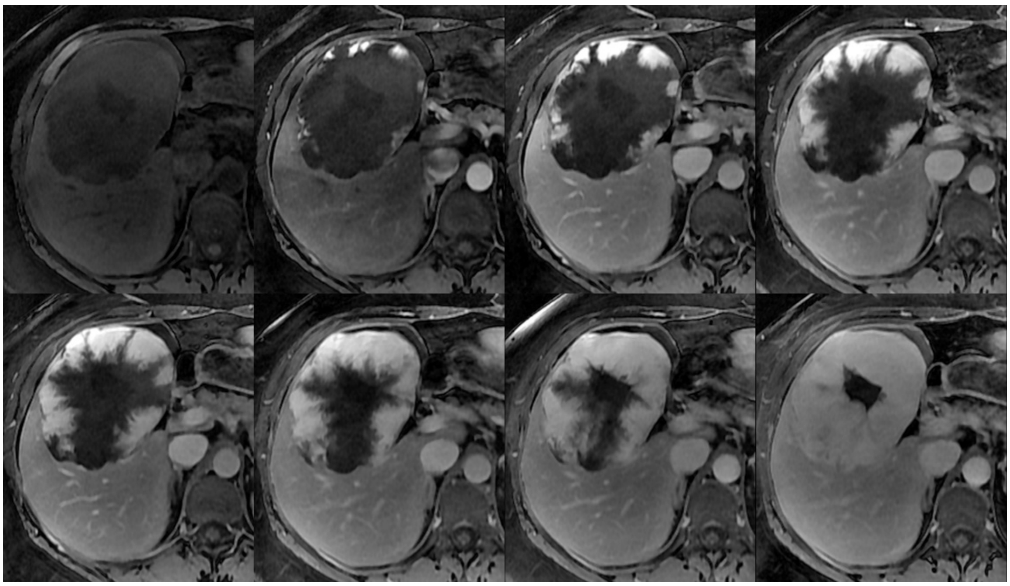
Peripheral Discontinuous Nodular Enhancement

RADLEX ID: RID43319

Characterization (Cont'd)

Example: MRI with ECA

Pre | Arterial Phase | PVP | 3 min DP



5 min | 10 min | 15 min | 20 min

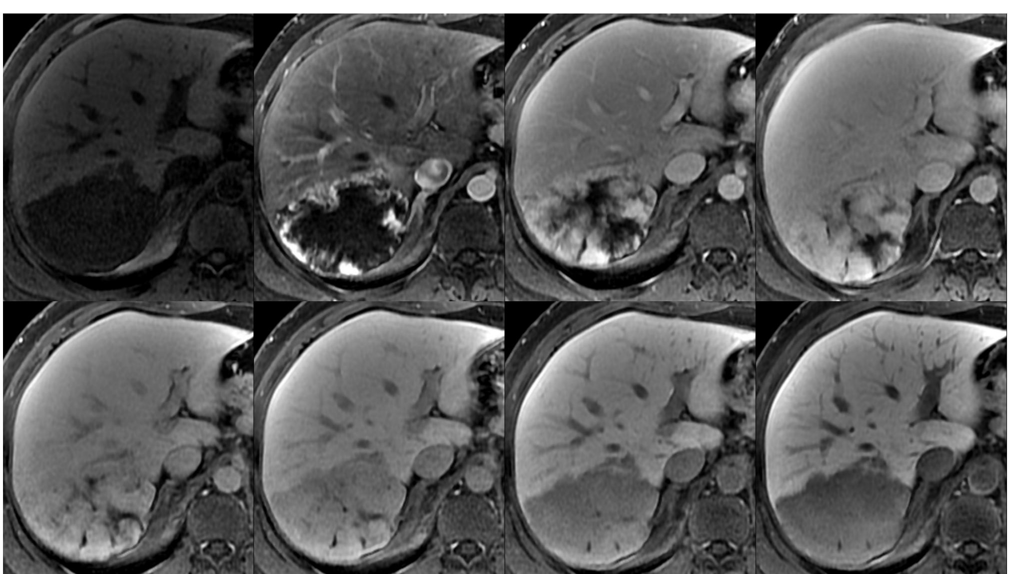
Giant (> 5 cm) hemangioma in noncirrhotic liver

As the nodular areas of enhancement expand on postarterial phase images, they approximately parallel the blood pool in brightness.

With ECA, the blood pool remains brighter than liver, so the enhancing areas of the hemangioma remain brighter, too

Example: MRI with gadoxetate disodium

Pre | Arterial Phase | PVP | 3 min DP



5 min | 10 min | 15 min | 20 min

Giant (> 5 cm) hemangioma in noncirrhotic liver

As the nodular areas of enhancement expand on postarterial phase images, they approximately parallel the blood pool in brightness.

With gadoxetate disodium, the blood pool becomes darker than liver, so the enhancing areas of the hemangioma become darker, too

Peripheral Discontinuous Nodular Enhancement

RADLEX ID: RID43319

Caution: Peripheral nodularity with central necrosis may resemble peripheral discontinuous nodular enhancement and cause diagnostic confusion and errors

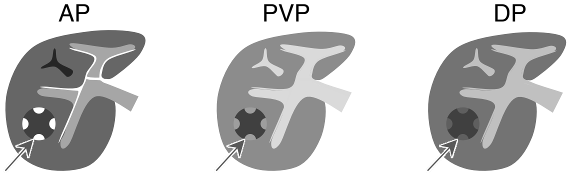
- Some malignant tumors have peripheral nodules. These nodules may resemble the peripheral enhancing puddles of hemangiomas.

- Clue to correct diagnosis: being solid tissue rather than blood spaces, the peripheral nodules in a malignant tumor do **not**
  - expand progressively
  - parallel the blood pool

Peripheral tumor nodules do not expand or parallel the blood pool in each postarterial phase

Extracellular agent or gadobenate

AP PVP DP

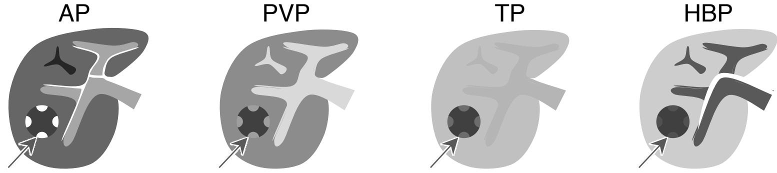


Matches arteries

Does not match vessels, does not expand

Gadoxetate

AP PVP TP HBP



Matches arteries

Does not match vessels, does not expand

Unlike the peripheral discontinuous pattern of hemangiomas, the peripheral tumor nodules do not expand and do not match the blood pool in enhancement on postarterial phase images

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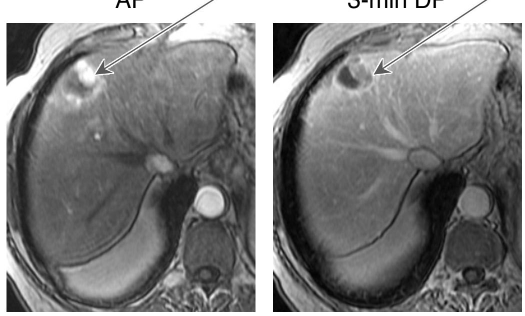
Example: MRI

Peripheral nodules enhance in AP

Peripheral nodules “wash out”, do not expand

AP 3-min DP



HCC with peripheral nodules, not to mistaken for hemangioma

Nonrim APHE

RADLEX ID: N/A

Definition

Spatially defined subtype of APHE in which APHE is NOT most pronounced in periphery of observation. APHE may have a range of appearances such as diffuse and homogeneous (uniform), diffuse and heterogeneous, scattered (patchy, spotty), nodule-in-nodule, or mosaic.

Synonyms

Arterial hypervascularity, hypervascularity in arterial phase, increased contrast enhancement in hepatic arterial phase, increased contrast enhancement in late hepatic arterial phase, hypervascularity, high attenuation area in arterial phase, contrast uptake in arterial phase, wash in.

Terminology

The term nonrim APHE is preferred since “nonrim APHE” is

- modality independent
- a descriptor of observation appearance that makes no assumptions (which may be false or simplistic) about underlying physiology, such as vascularity

Additionally, the term nonrim APHE is clear, unambiguous, and the logical counterpart to the other spatial subtype (rim APHE).

The term nonrim APHE is not used commonly in the radiology literature, however. For simplicity and to keep jargon to a minimum, the general term “APHE” may be used instead of the more specific term “nonrim APHE” if its usage in this way is unambiguous.

Applicable imaging methods

CT, MRI (all contrast agents)

Type of feature

Major feature of HCC, required for LR-5

Nonrim APHE

RADLEX ID: N/A

Effect on categorization

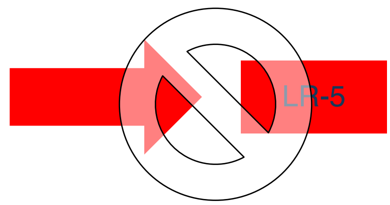
Nonrim APHE is required for LR-5.

Only observations with nonrim APHE can be categorized LR-5.

As a corollary, the absence of nonrim APHE precludes LR-5 categorization.

Pre | **Arterial Phase**

No nonrim APHE



Nonrim APHE

RADLEX ID: N/A

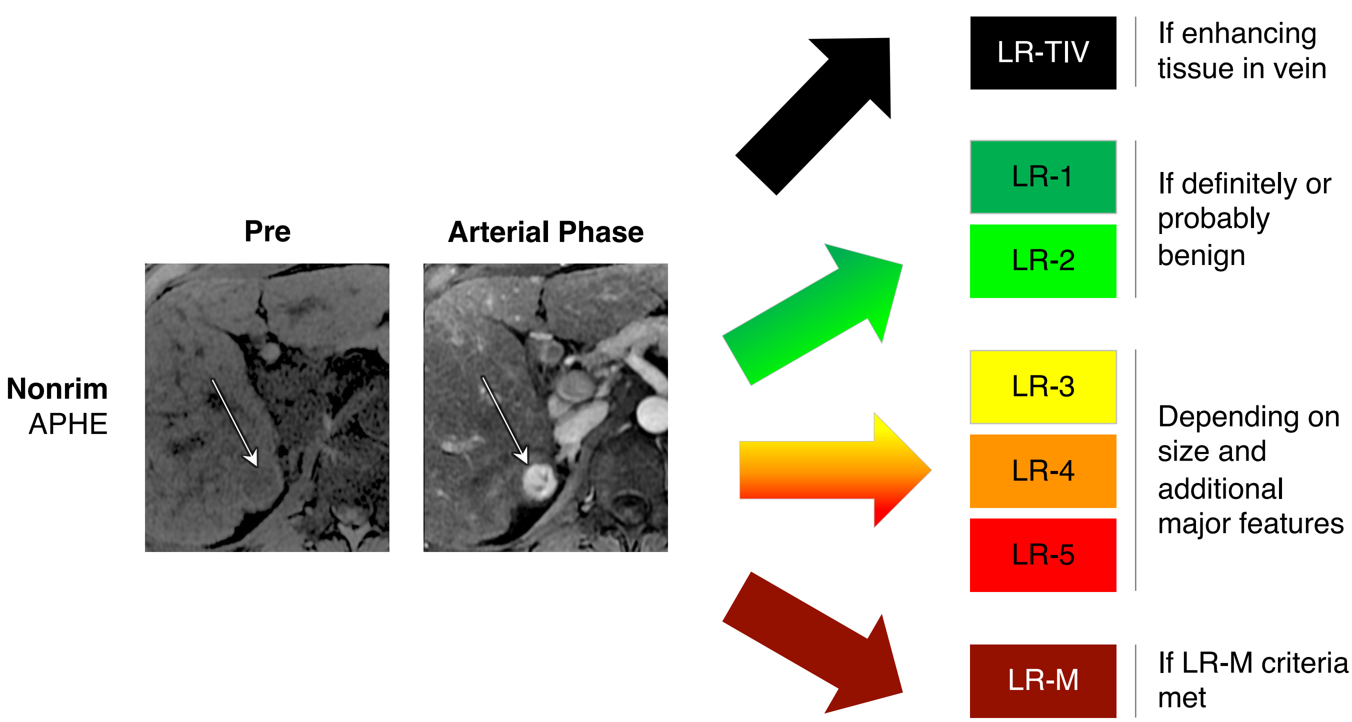
Effect on categorization (Cont'd)

Nonrim APHE is not sufficient for LR-5.

Observations with nonrim APHE *can* be other than LR-5.

For example, observations with nonrim APHE can be

- LR-TIV (if enhancing soft tissue in vein)
- LR-1 or LR-2 (if definitely or probably benign)
- LR-M (if LR-M criteria met)
- LR-3, LR-4, LR-5 (depending on size and additional major features)



Nonrim APHE is not specific for HCC

Although nonrim APHE is a major feature of and required for LR-5 categorization, it is not by itself specific for HCC. As shown above, observations with nonrim APHE can span the entire spectrum of LI-RADS categories depending on other features.

Nonrim APHE

RADLEX ID: N/A

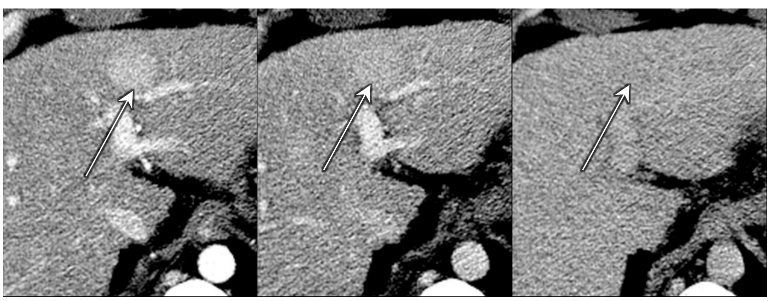
Effect on categorization (Cont'd)

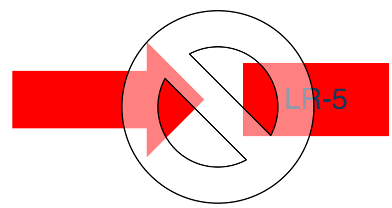
APHE is not sufficient for LR-5 (Cont'd)

Example: CT

25 mm observation with nonrim APHE. Observation has no additional features of HCC (i.e., no "washout", no "capsule"). Threshold growth is not applicable (no prior exams). Without additional major features of HCC, observation cannot be categorized LR-5, despite presence of APHE. Instead, it is categorized LR-4. As illustrated in this case, APHE does not suffice for LR-5.

AP **PVP** **3-min DP**



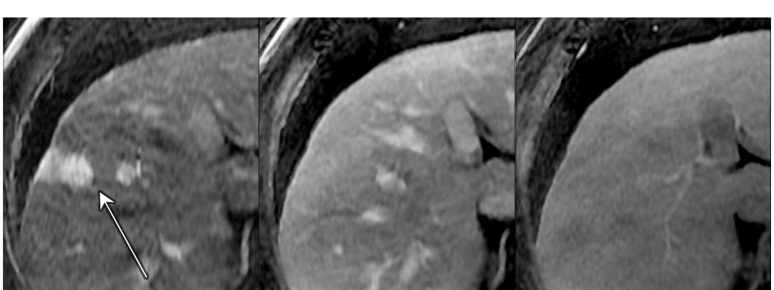


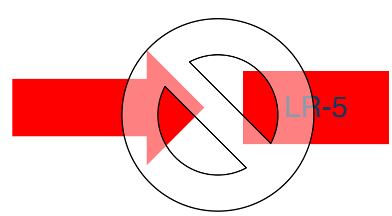
≥ 20-mm APHE with **NO** additional major feature

Example: MR

22 mm observation with nonrim APHE. No additional features of HCC (i.e., no "washout", no "capsule"). Threshold growth not applicable no prior exams). Without additional major features of HCC, observation cannot be categorized LR-5, despite presence of APHE. In this case, observation was interpreted as LR-2 probable nodular perfusion alteration due to AP shunting (clues to this categorization: occult in TP, HBP; nonmasslike appearance on arterial phase multiplanar reformats [not shown]). Follow-up imaging 6 months later showed spontaneous disappearance, confirming diagnosis of benign perfusion alteration. As illustrated in this case, APHE does not suffice for LR-5.

AP **PVP** **3-min TP**





≥ 20-mm APHE with **NO** additional major feature

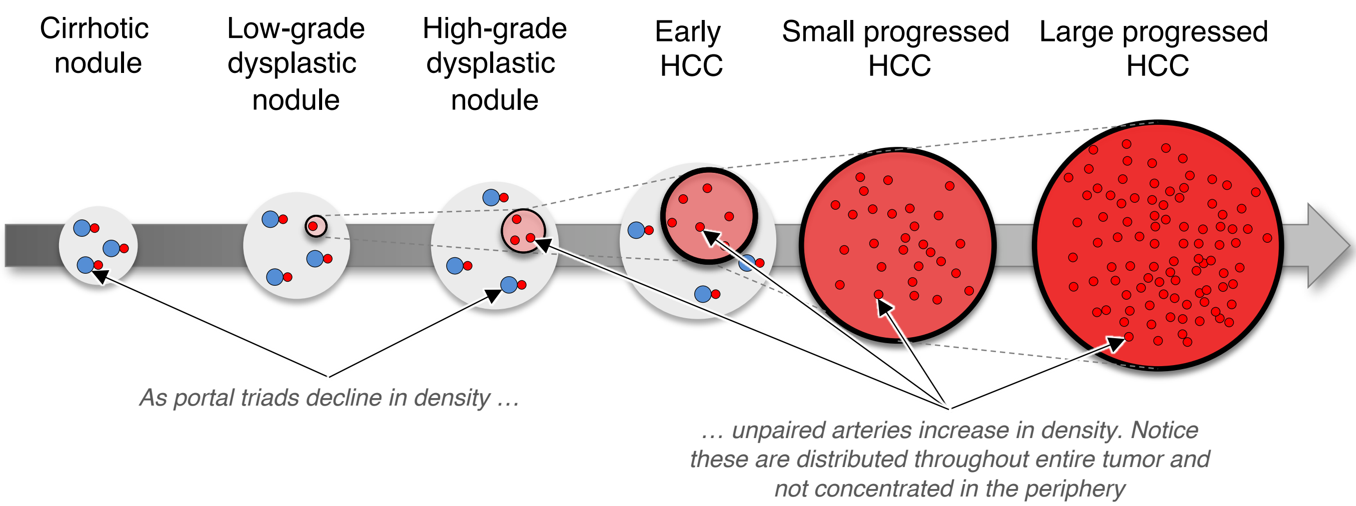
Nonrim APHE

RADLEX ID: N/A

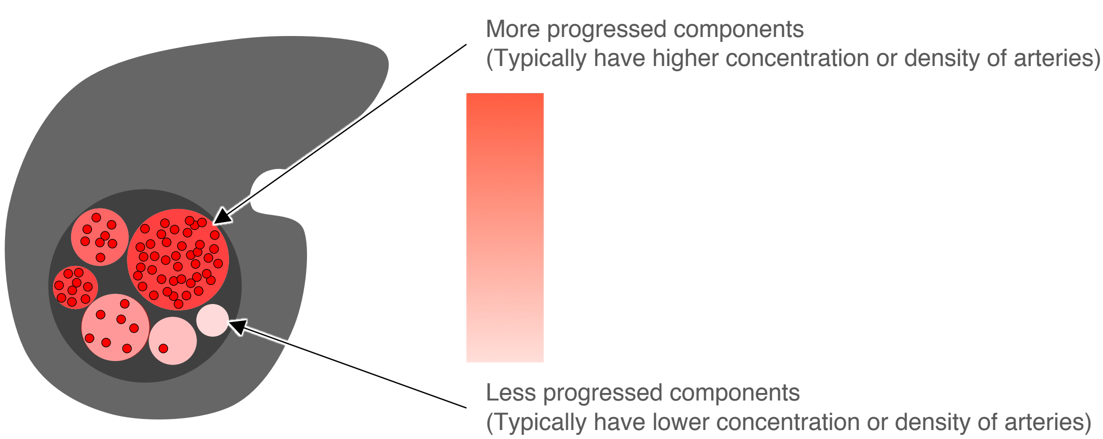
Biological basis

Nonrim APHE reflects neovascularity distributed throughout the entire tumor and not just concentrated in the tumor periphery. As hepatocellular nodules evolve to form HCC, the dual blood supply from the arterial and portal circulations gradually diminishes while unpaired neoarteries are formed (neoangiogenesis). Eventually, the arterial supply from the unpaired neoarteries exceeds the arterial supply to the background liver. Generally, these arteries supply the whole tumor, not just the tumor periphery, although the distribution may be heterogeneous.

The unpaired arteries that form during hepatocarcinogenesis are distributed throughout and supply the whole tumor.



If the tumor architecture is nodule-in-nodule or mosaic, these vessels preferentially supply the more progressed (more malignant, less differentiated) components.



Nonrim APHE

RADLEX ID: N/A

Biological basis (Cont'd)

In most HCCs, the intranodular arteries are too small to be seen on CT or MRI.

In some HCCs, however, the internal arteries are unusually large and can be seen.

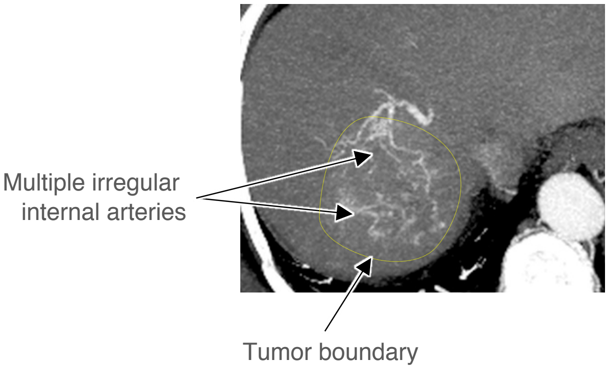
These arteries tend to be irregular.

Intratumoral pseudoaneurysms may be evident.

Example 1: CT

Arterial Phase

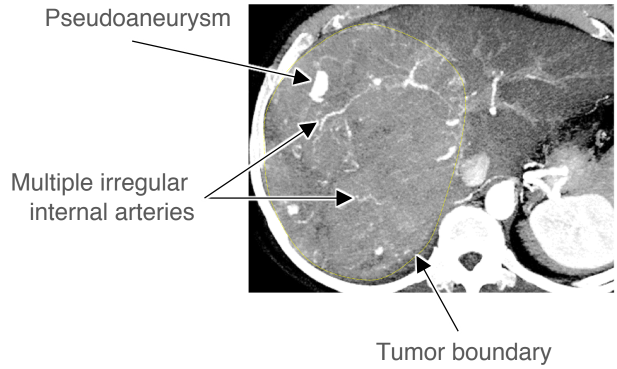
30-mm MIP



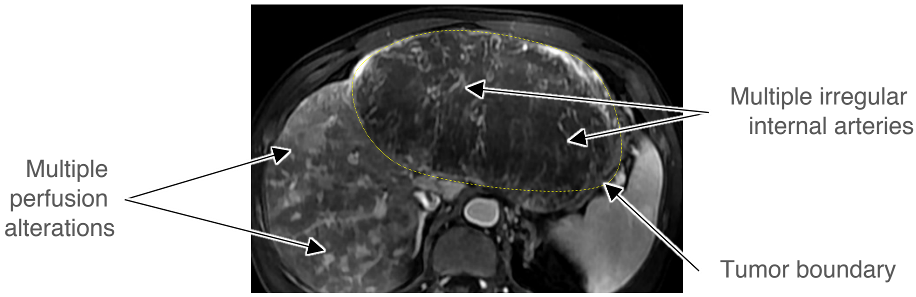
Example 2: CT

Arterial Phase

60-mm MIP



Example: MRI



Nonrim APHE

RADLEX ID: N/A

Summary of evidence

Nonrim APHE is the most sensitive dynamic contrast enhancement feature for diagnosis of progressed (overtly malignant) HCC.

APHE has reported sensitivities ranging from 65-96% for progressed HCC in at-risk patients. The sensitivity is lower for early HCCs due to incomplete neovascularization in these well-differentiated tumors.

Nonrim APHE by itself lacks specificity for HCC (ranging from 62 to 97%), as this feature can be present in benign entities (e.g. hemangiomas and perfusion anomalies), premalignant lesions such as dysplastic nodules, and even small non-HCC malignancies such as iCCAs and cHCC-CCAs.

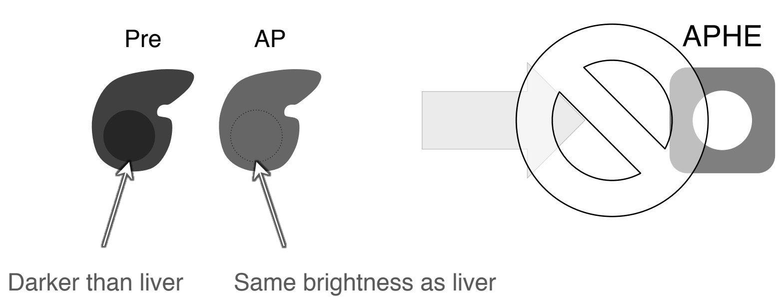
However, it can diagnose HCC with 100% PPV in the appropriate population, if applied stringently in conjunction with additional major features (e.g., washout appearance, capsule appearance).

For these reasons, nonrim APHE is included in all diagnostic imaging algorithms as a major criterion for HCC. Although most algorithms do not specify “nonrim APHE” in particular, it is implied.

Comment

Although there is scientific evidence supporting APHE as a major feature of HCC, there is little evidence to inform its exact definition, as the literature has been unclear on this issue. Thus, the LI-RADS definition of APHE was developed mainly on expert opinion. In particular, in the current LI-RADS definition, the following enhancement pattern does NOT qualify as APHE: dark (pre) → iso (arterial phase)

dark (pre) → iso (arterial phase) is **NOT** APHE



Research is needed to validate the LI-RADS definition or inform its refinement.

Nonrim APHE

RADLEX ID: N/A

Characterization

Characterize on arterial phase images. Late arterial phase images are usually more reliable for detecting APHE than early arterial phase images.

See *page 16-18* for general concepts about APHE and *page 16-26* for use of subtractions.

Nonrim APHE is present if **ALL** of the following are met:

- Observation in whole or in part enhances more than liver in arterial phase

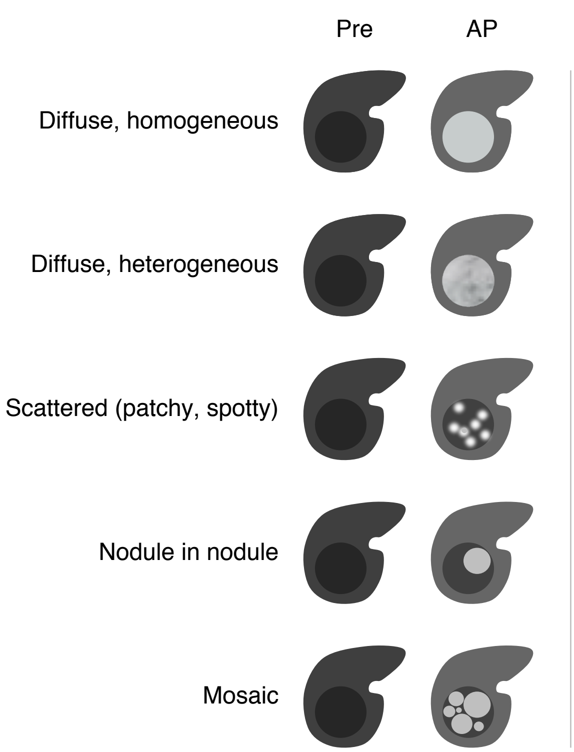
  AND

- Enhancing part is brighter than liver in arterial phase

  AND

- Enhancement is not confined to the rim

Nonrim APHE can be diffuse and homogeneous, diffuse and heterogeneous (nonuniform), scattered (patchy, spotty), nodule-in-nodule, or mosaic.



Any of these spatial patterns qualifies as APHE so long as the enhancement is unequivocal.

There is no minimum size for application of APHE, rather its presence should be unequivocal in judgment of radiologist.

These patterns have variable specificity for HCC. See *page 16-76* and *16-77*.

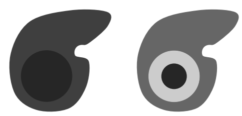
Nonrim APHE

RADLEX ID: N/A

Characterization (Cont'd)

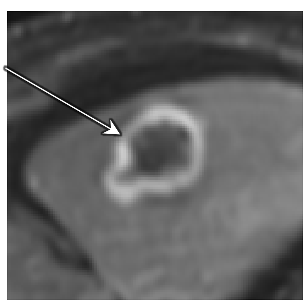
Nonrim APHE should not be confused with rim APHE.

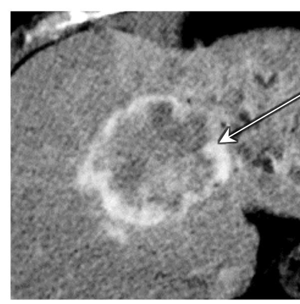
Rim



Rim enhancement is continuous and most pronounced along periphery. By itself, this suffices to categorize an observation as LR-M.

Rim APHE



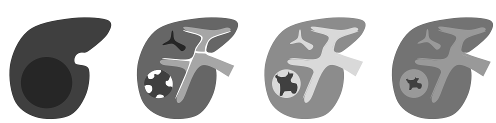


Rim APHE

Caveat: Peripheral discontinuous nodular enhancement is a special case.

Pre AP PVP DP

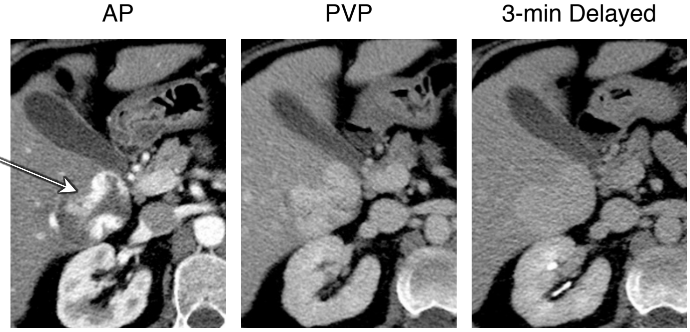
Peripheral nodular discontinuous



Peripheral discontinuous nodular enhancement that expands on postarterial phases while paralleling the blood pool in brightness is diagnostic of hemangioma.

AP PVP 3-min Delayed

Discontinuous puddles on AP



Nonrim APHE

RADLEX ID: N/A

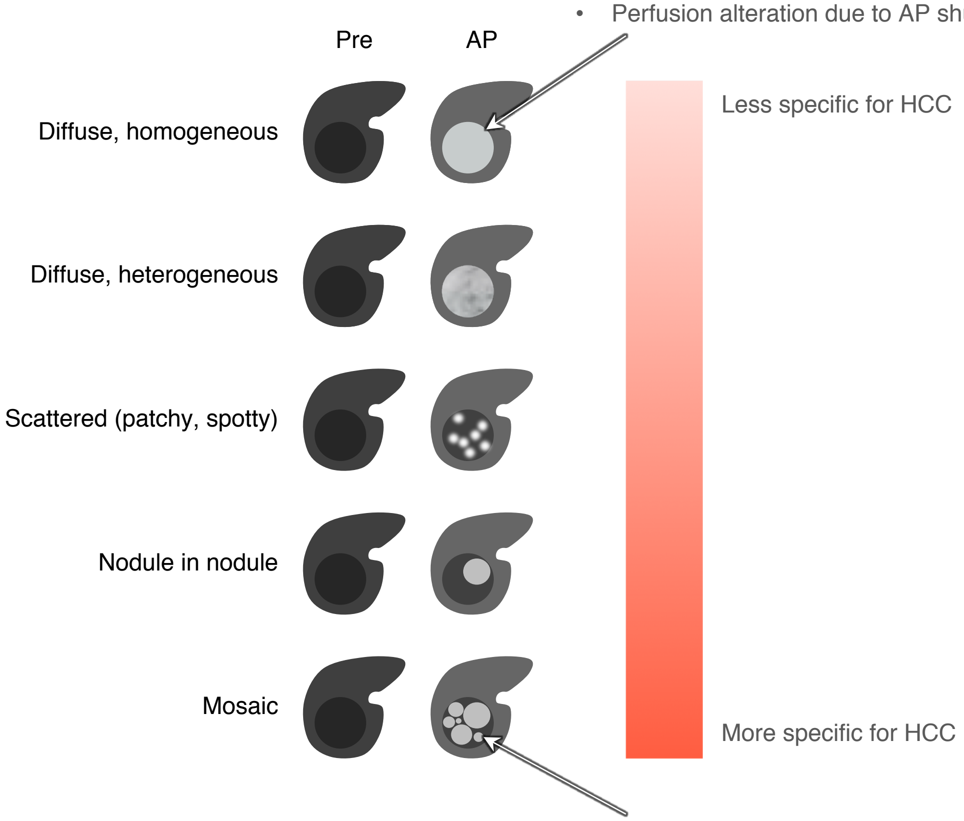
Characterization (Cont'd)

Five patterns of nonrim APHE have variable specificity for HCC

Below they are listed in order of specificity from least specific (top) to most specific (bottom)

Differential diagnosis in high-risk patients of diffuse homogeneous APHE

- Small HCC
- Small iCCA
- Small cHCC-CCA
- Small other non-HCC malignancies
- Dysplastic nodule
- Rapidly enhancing hemangioma
- Perfusion alteration due to AP shunt or other cause



Differential diagnosis in high-risk patients of mosaic APHE

- Progressed HCC
- Atypical:
  - iCCA
  - cHCC-CCA
  - Other non-HCC malignancies

Nonrim APHE

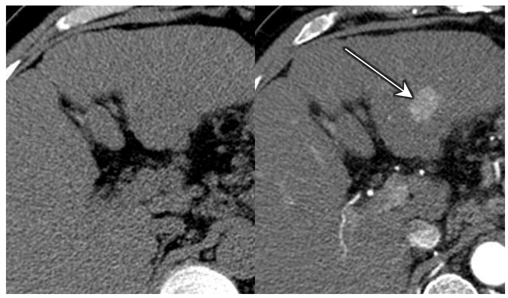
RADLEX ID: N/A

Characterization (Cont'd)

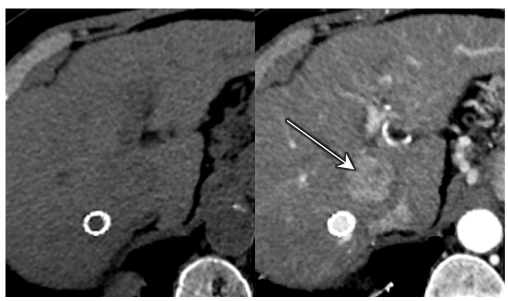
Examples: CT

Pre AP

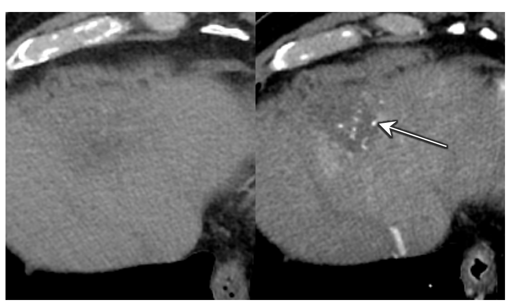
Nonrim APHE:
Homogeneous



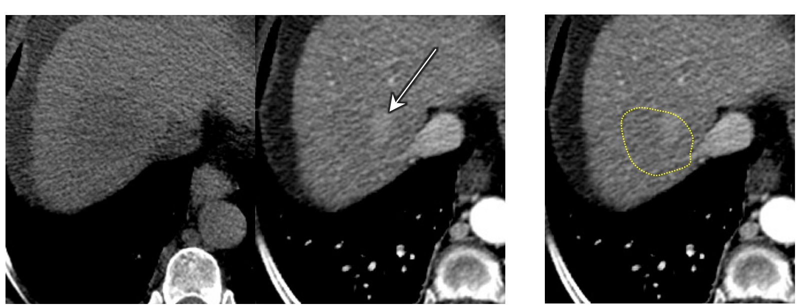
Nonrim APHE:
Heterogeneous



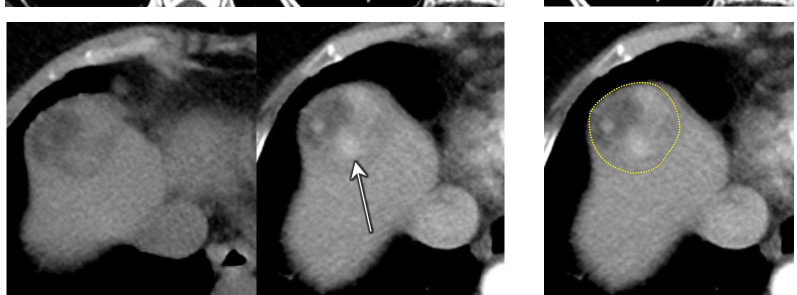
Nonrim APHE:
Scattered (patchy, spotty)



Nonrim APHE:
Nodule-in-nodule



Nonrim APHE:
Mosaic



Nonrim APHE

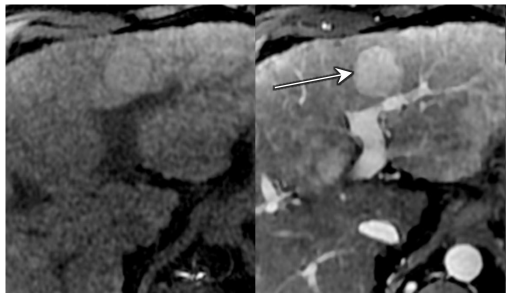
RADLEX ID: N/A

Characterization (Cont'd)

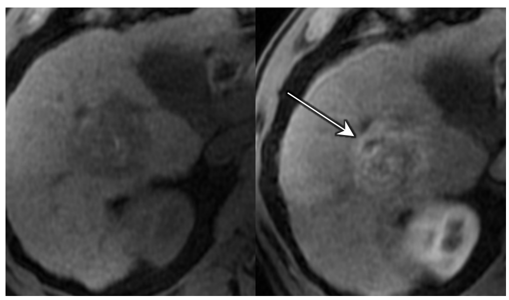
Examples: MRI

Pre AP

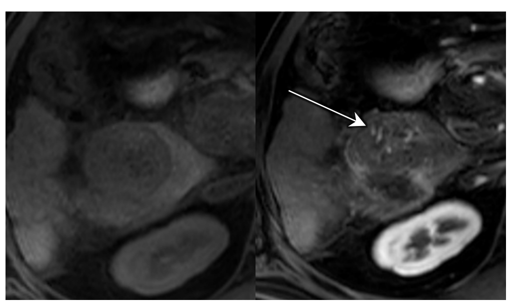
Nonrim APHE:
Homogeneous



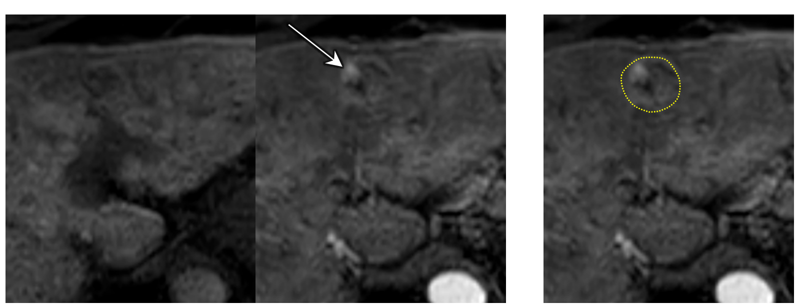
Nonrim APHE:
Heterogeneous



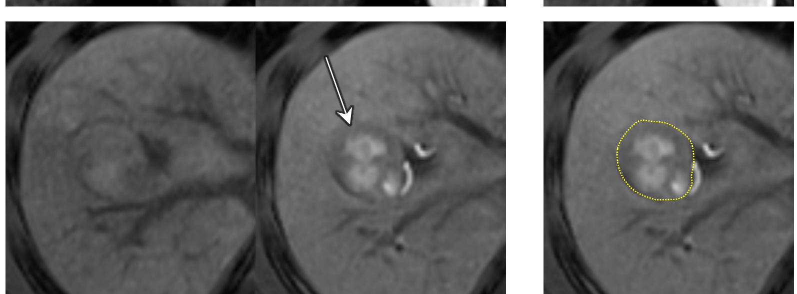
Nonrim APHE:
Scattered (patchy, spotty)



Nonrim APHE:
Nodule-in-nodule



Nonrim APHE:
Mosaic



Nonrim APHE

RADLEX ID: N/A

Characterization (Cont'd)

If unsure

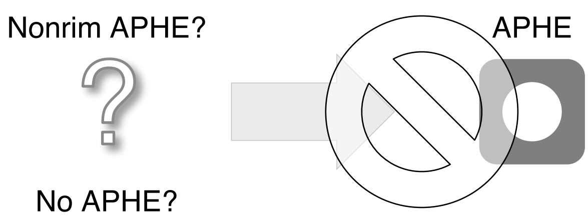
If unsure about nonrim APHE vs. no APHE: characterize as no APHE

- *Rationale: LI-RADS imaging features are characterized as present only if there is certainty*

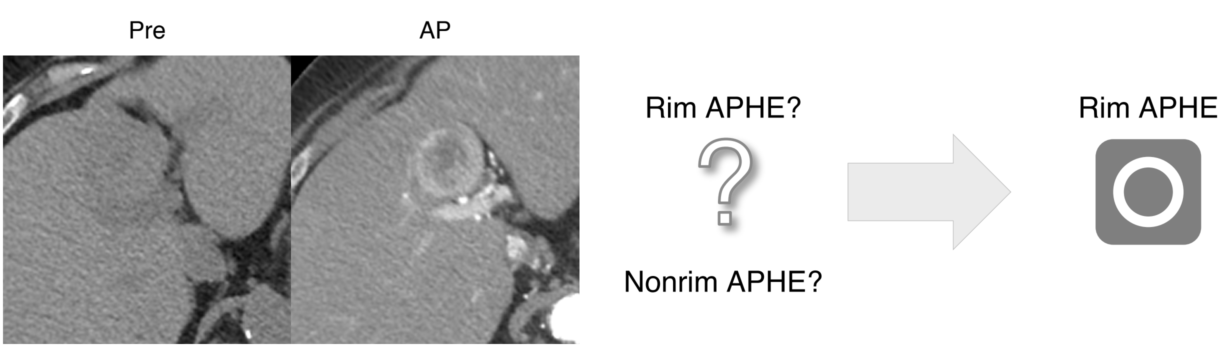
If unsure about rim APHE vs nonrim APHE, characterize as rim APHE

- *Rationale: provides low threshold for alerting referrer to possibility of non-HCC malignancy*

Example: nonrim APHE vs no APHE, characterize as no APHE



Example: rim APHE vs nonrim APHE, characterize as rim APHE



Nonrim APHE

RADLEX ID: N/A

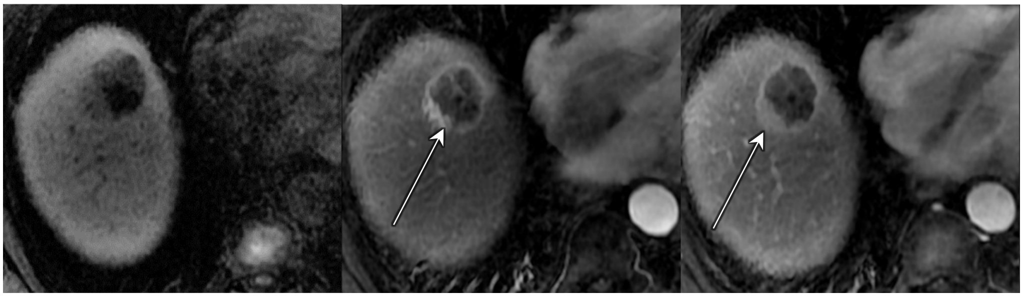
Pitfalls & practical considerations

Not all HCCs have any APHE.

Some HCCs have rim APHE, rather than nonrim APHE.

Example: MRI

Pre | **Arterial Phase** | **PVP**



Path-proven atypical HCC with rim APHE

This was categorized LR-M based on rim APHE. Biopsy indicated HCC

As illustrated in this case, some HCCs can have rim APHE. See *page 16-47* for more information.

Nonrim APHE is not specific for HCC and can be seen in a wide spectrum of other observations:

- Hemangiomas
- Perfusion alterations
- Dysplastic nodules
- Small non-HCC malignancies

As stated on *page 16-18*, APHE requires **BOTH** greater enhancement **AND** greater brightness than liver in the arterial phase. Observations that are darker than liver precontrast and enhance to become isointense or isoattenuating in the arterial phase do not have APHE by definition, since they fail to meet the second requirement. The requirement for greater brightness than liver, not just greater enhancement, is intended to reduce false-positive diagnoses of HCC. It is based on expert opinion as the literature is unclear on this issue.

Compared with other MR agents, gadoxetate disodium is less likely to depict nonrim APHE. See *Chapter 13, page 13*.

Nonrim APHE

RADLEX ID: N/A

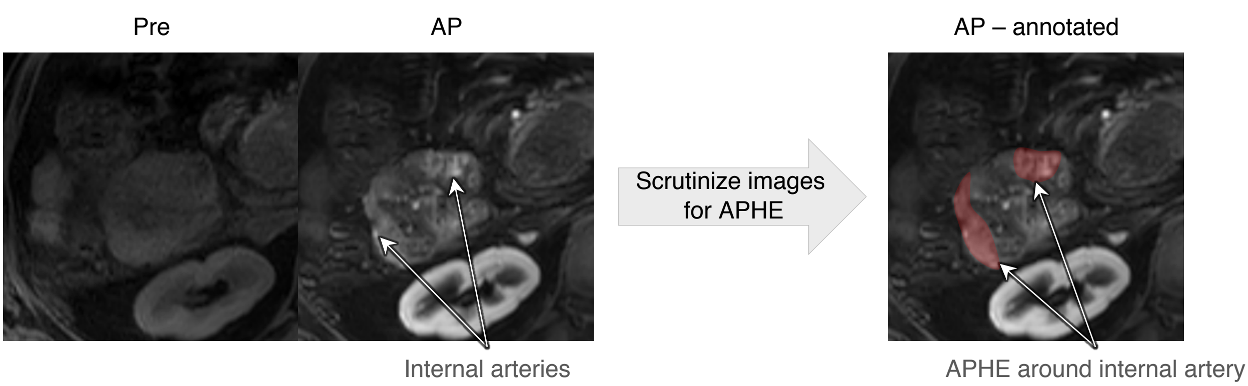
Pitfalls & practical considerations (Cont'd)

Although nonrim APHE is usually most conspicuous in the late AP, it is occasionally more conspicuous in the early AP (i.e., earlier than expected) or PVP (i.e., later than expected). See *page 16-34)*.

There is no minimum size for application of nonrim APHE, rather its presence should be unequivocal in the radiologist's judgment.

Subtractions are sometimes useful for characterizing nonrim APHE. See *page 16-26* for discussion of subtractions.

Some HCCs have irregular internal arteries visible on CT and MRI. If a mass has irregular internal arteries visible on CT and MRI, scrutinize the mass for APHE around the arteries.



Nonrim APHE

RADLEX ID: N/A

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Nonrim APHE

RADLEX ID: N/A

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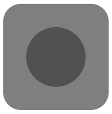
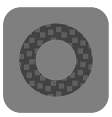
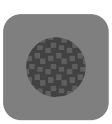
Washout Appearance (“Washout”) & its Subtypes

Feature	**Definition**	*Page*
“Washout” 	Visually assessed temporal reduction in enhancement in whole or in part relative to composite liver tissue from earlier to later phase resulting in hypoenhancement in the postarterial extracellular phase. “Washout” may be peripheral or nonperipheral (see below).	*16-84*

“Washout” subtypes

Feature	**Definition**	*Page*
Peripheral ‘Washout” 	Spatially defined subtype of “washout” (WO) in which apparent washout is most pronounced in observation periphery. Peripheral WO is a targetoid LR-M feature. By itself, peripheral “washout” is enough for LR-M categorization. Thus, all untreated observations with peripheral “washout” should be categorized LR-M, with 2 exceptions. Exceptions: • If there is tumor in vein, categorize as LR-TIV. • If observation is path-proven malignant neoplasm or path-proven nonhepatocellular benign entity, report path diagnosis, not LI-RADS category. Peripheral WO is not required for LR-M categorization. Thus, observations *can* be categorized LR-M even if lacking peripheral WO.	*16-125*
Nonperipheral “Washout” 	Spatially defined subtype of WO in which apparent washout is NOT most pronounced in observation periphery. WO can be diffuse and homogeneous, diffuse and heterogeneous (nonuniform), scattered (patchy, spotty), nodule-in-nodule, or mosaic. The area(s) of WO needs to enhance in earlier phases but need not show APHE. Nonperipheral WO is a major additional feature of HCC, but it is not required for LR-5 categorization. Thus, observations *can* be categorized LR-5 even if lacking rim APHE. By itself, nonperipheral WO is **not** enough for LR-5 categorization. Thus, observations with nonperipheral WO can be categorized LR-5 *only* in combination with other features. See *CT/MRI Diagnostic Table*.	*16-138*

Caveats and practical considerations

With ECA: combination of PVP & DP more sensitive than PVP alone for detecting WO	*16-119*
With gadoxetate: WO must be characterized in the PVP, not the transitional phase	*16-120*

Washout Appearance (“Washout”)

RADLEX ID: RID39486

Definition

Visually assessed temporal reduction in enhancement in whole or in part relative to composite liver tissue from earlier to later phase resulting in hypoenhancement in the postarterial *extracellular phase*, i.e.:

- For ECA and gadobenate: hypoenhancement in PVP, DP, or both
- For gadoxetate: hypoenhancement in PVP only. Hypointensity in TP or HBP does not qualify as “washout”. *See page 16-98*.

“Washout” has two subtypes:

- Peripheral “washout”: *page 16-125*
- Nonperipheral “washout”: *page 16-138*

Synonyms

Washout; venous/portal venous/delayed/late phase hypoenhancement, hypoattenuation, or hypointensity; deenhancement

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Terminology

For CT and MRI, the term washout appearance or “washout” is preferred because

- It is modality independent
- the visually assessed temporal reduction in enhancement relative to liver may be due to progressive liver enhancement rather than observation deenhancement. That is, it may not represent true washout.

Depending on context, LI-RADS may use the term “washout” to refer to “washout” generically or, for simplicity, to refer specifically to nonperipheral “washout” (the more common “washout” subtype).

Note: The terminology is different for CEUS, where the use of quotation marks around washout is unnecessary. See CEUS LI-RADS (pending).

Applicable imaging methods

CT, MRI

Washout Appearance ("Washout")

RADLEX ID: RID39486

Type of feature

For CT and MRI, depends on spatial subtype:

- Peripheral "washout": feature of non-HCC malignancy, sufficient for LR-M, excludes LR-5.
  - See page 16-9.
- Nonperipheral "washout": major feature for HCC, but neither required nor sufficient for LR-5.
  - See page 16-139.

Note:

For CEUS, the type of feature depends on the time of onset and degree of washout, not its spatial subtype. See CEUS LI-RADS (pending).

Effect on categorization

Depends on the spatial subtype of "washout", as illustrated in next few pages.

Washout Appearance (“Washout”)

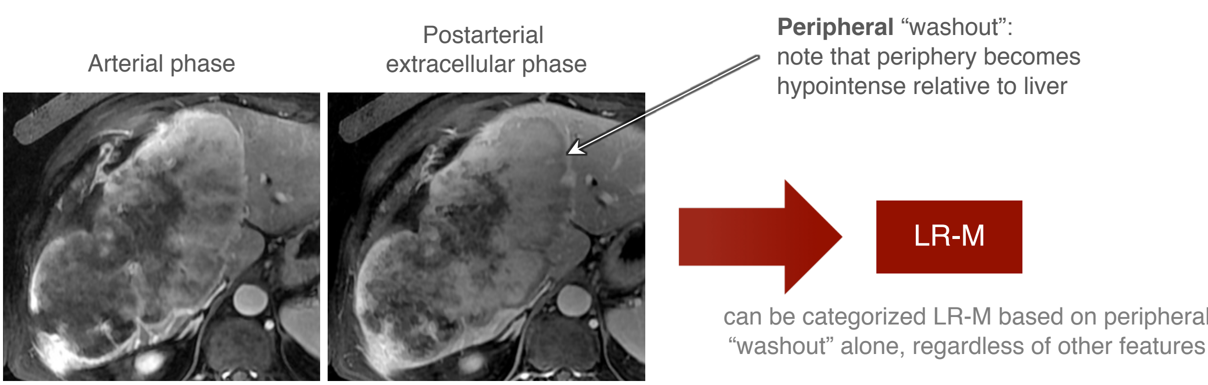
RADLEX ID: RID39486

Effect on categorization (Cont’d)

Peripheral “washout” is sufficient for LR-M.

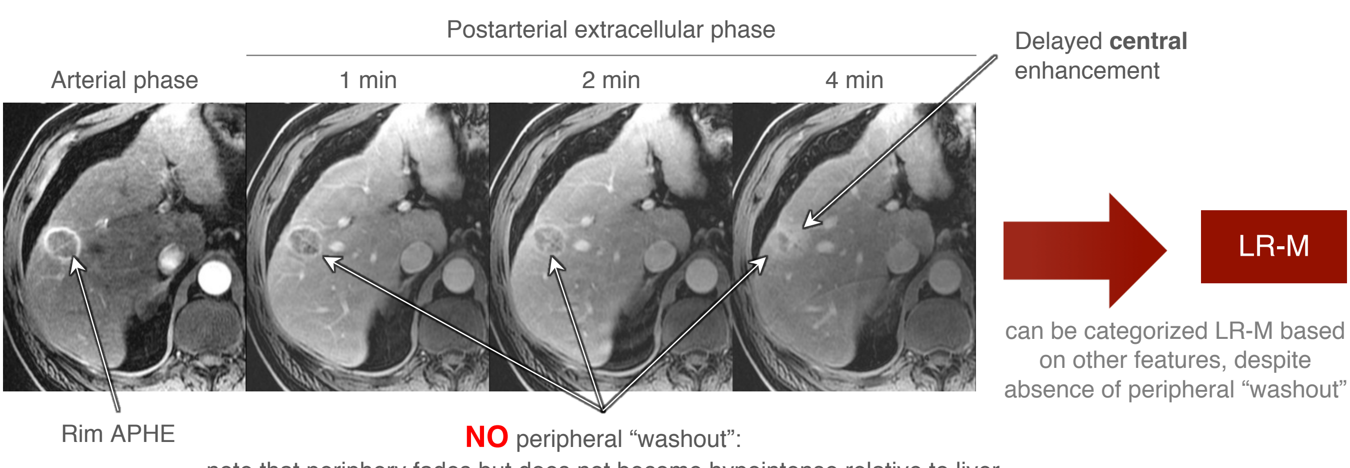
By itself, peripheral “washout” is enough for LR-M. Thus, all untreated observations with peripheral “washout” are LR-M, regardless of other imaging features.

- Exceptions:
  - If there is tumor in vein, categorize as LR-TIV.
  - If observation is path-proven malignant neoplasm or path-proven nonhepatocellular benign entity, report path diagnosis, not LI-RADS category.



Peripheral “washout” is not required for LR-M.

Observations without peripheral “washout” can be LR-M if other LR-M features are present (see *page 16-9*). Example: rim APHE and delayed central enhancement but not peripheral “washout”



Washout Appearance (“Washout”)

RADLEX ID: RID39486

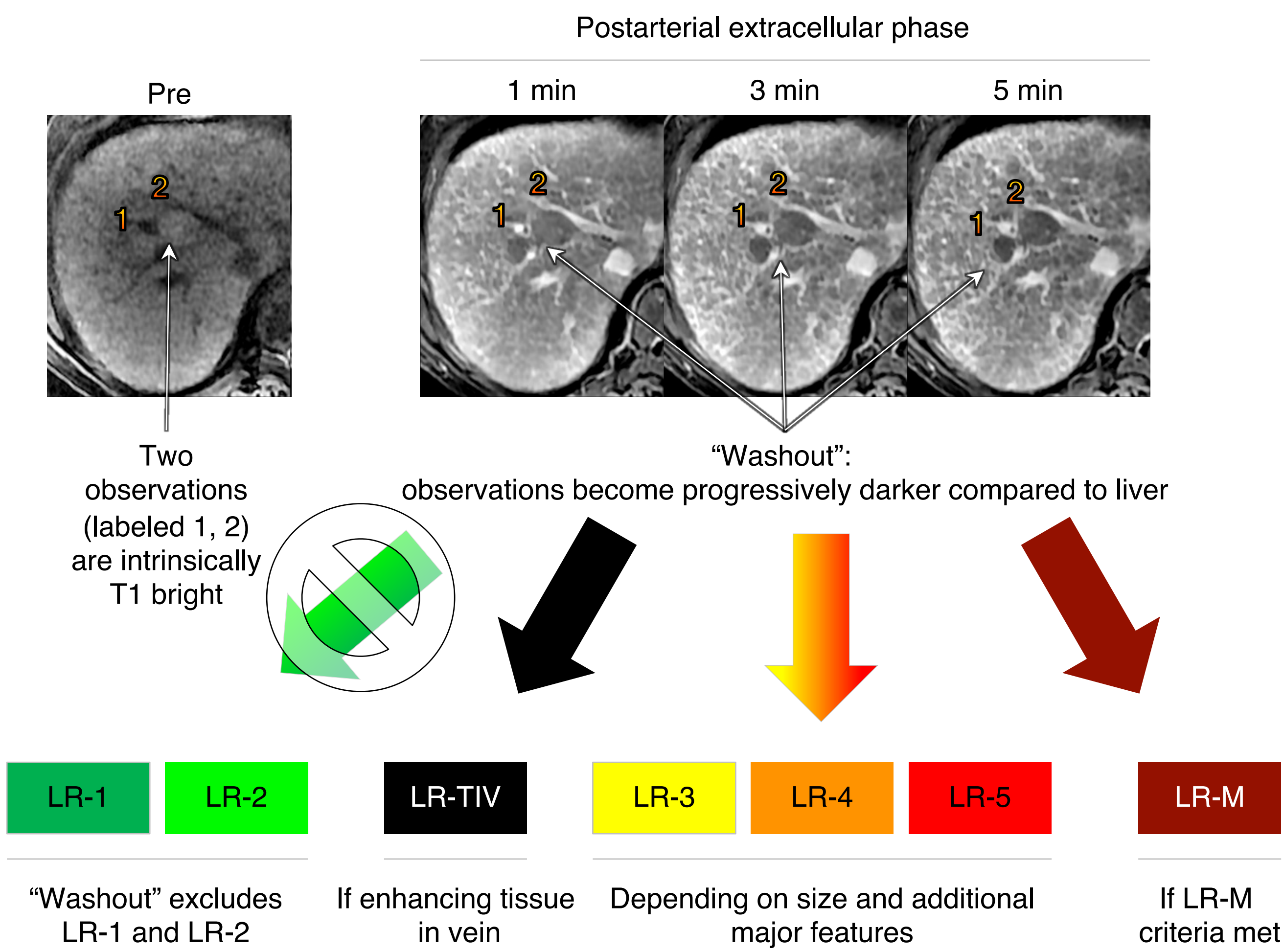
Effect on categorization (Cont’d)

Nonperipheral “washout” is a major feature of HCC.

- In combination with other features, nonperipheral “washout” allows LR-5 categorization. However, it is neither sufficient nor required for LR-5.

Nonperipheral “washout” is not sufficient for LR-5.

- Observations with nonperipheral “washout” *can* be other than LR-5. For example, observations with nonperipheral “washout” can be:
  - LR-TIV (if enhancing soft tissue in vein)
  - LR-M (if LR-M features are present on other images)
  - LR-3, LR-4, LR-5 (depending on size and additional major features)



Washout Appearance ("Washout")

RADLEX ID: RID39486

Effect on categorization (Cont'd)

Nonperipheral "washout" excludes LR-1 and LR-2.

- Observations with "washout" must be categorized LR-3 or higher (see prior page)
- One exception: at radiologist's discretion, an LR-3 observation with "washout" can be downgraded to LR-2 by ancillary features favoring benignity

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Nonperipheral "washout" is not required for LR-5.

- Observations without "washout" *can* be LR-5.
  - For example, a ≥ 20-mm observation with APHE and "capsule" but without "washout" is LR-5. *See CT/MRI Diagnostic Table*.

Arterial Phase | PVP | 3 min DP

enhancing "capsule"
(i.e., rim around lesion is unequivocally brighter than fibrosis around background nodules)

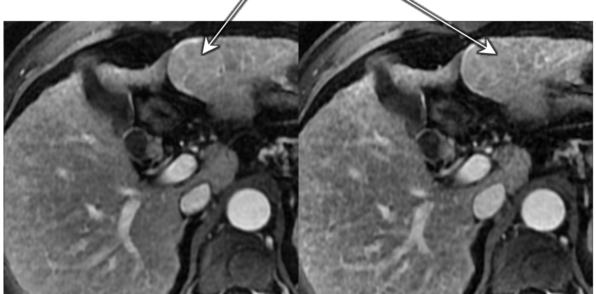
LR-5

can be categorized LR-5 based on other features, despite lacking nonperipheral "washout"

Nonrim APHE

NO "washout"
(lesion inside is not darker than composite liver outside)

"Capsules" can create the false perception of "washout". To verify the absence of "washout", the lesion "capsule" from the 12 o'clock to the 7 o'clock position was removed electronically.



Images electronically altered for illustrative purposes

Washout Appearance ("Washout")

RADLEX ID: RID39486

Biological basis

For peripheral "washout": see page 16-127.

For nonperipheral "washout": see page 16-143.

Summary of evidence

For peripheral "washout": see page 16-127.

For nonperipheral "washout": see page 16-144.

Washout Appearance (“Washout”)

RADLEX ID: RID39486

Characterization

Peripheral “washout” and nonperipheral “washout” are mutually exclusive subtypes.

- If “washout” is most pronounced in observation periphery, characterize as peripheral “washout”, NOT nonperipheral “washout”. For more information on characterization of

- Peripheral “washout”, see page 16-128.
- Nonperipheral “washout”, see page 16-145.

Characterize by comparing postarterial extracellular phase images:

- For ECA and gadobenate: PVP, DP, or both. DP images may be more sensitive for characterizing “washout” than PVP using these agents. See page 16-119.
- For gadoxetate: PVP only. “Washout” cannot be characterized on TP or HBA using this agent. See page 16-120.

Washout appearance is present if **BOTH** of the following are met:

- The observation enhances to at least some degree: completely nonenhancing observations (e.g., cysts) cannot be characterized as having “washout”. See page 16-111.

  AND

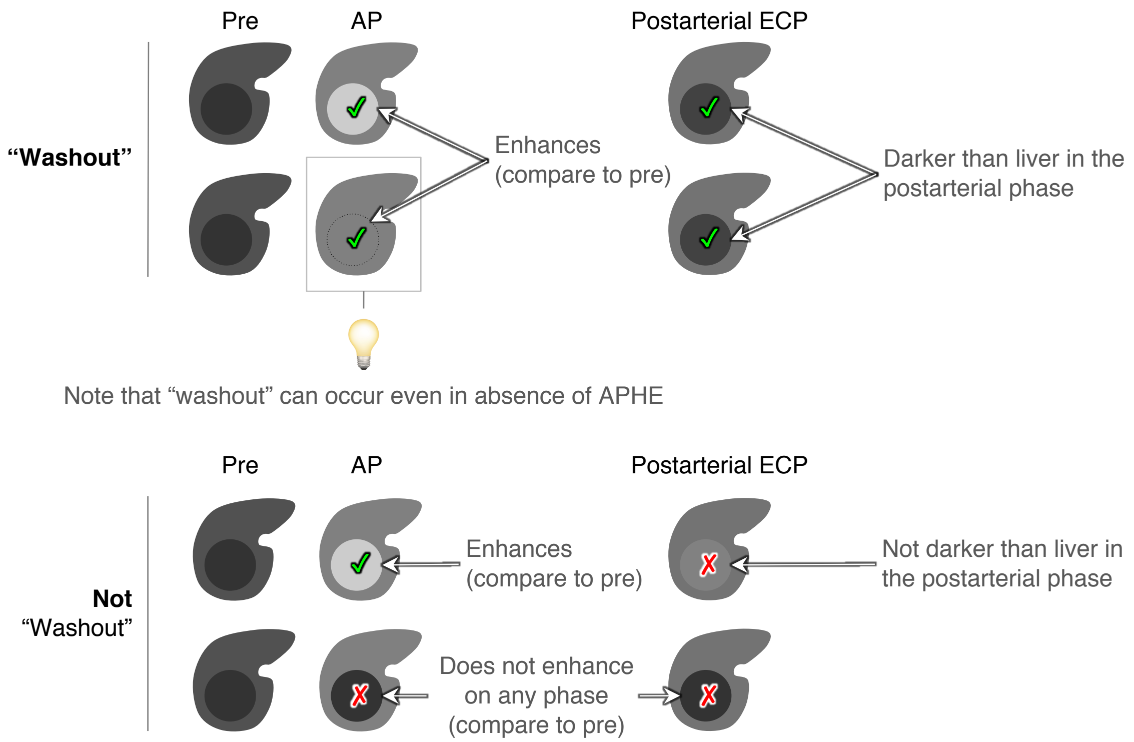
- Be darker than liver in the postarterial extracellular phase source images or (postarterial extracellular phase – precontrast) subtraction images (see page 16-104 for use of subtractions).

Washout Appearance ("Washout")

RADLEX ID: RID39486

Characterization (Cont'd)

Note that APHE is not required. Peripheral "washout" can occur even in absence of APHE so long as observation enhances to some degree.



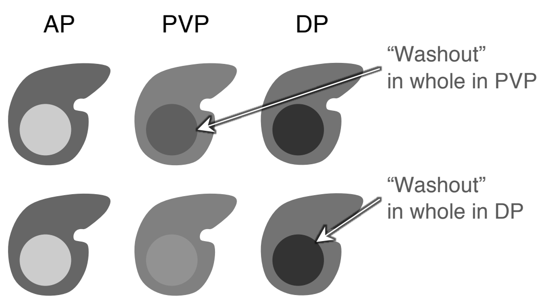
Washout Appearance (“Washout”)

RADLEX ID: RID39486

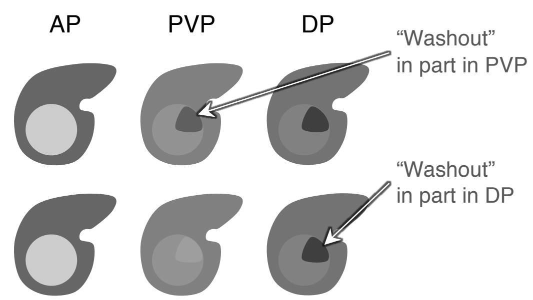
Characterization (Cont’d)

“Washout” may be in whole or in part:

“Washout” in Whole

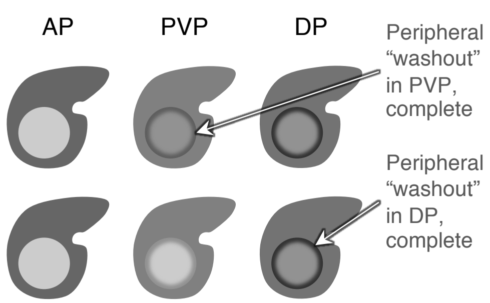


“Washout” in Part

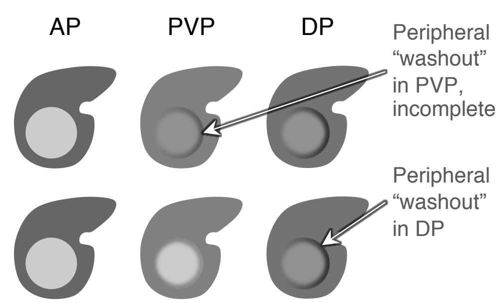


Peripheral “washout” may be compete or incomplete

Peripheral “washout”, Complete



Peripheral “washout”, Incomplete



There is no minimum number of pixels to gauge whether “washout” is present or if it is peripheral or nonperipheral.

- Rather, its presence and subtype must be unequivocal in the radiologist’s judgment
- Rationale: there is no scientific data to guide an optimal threshold. Any imposed threshold would be arbitrary

Washout Appearance ("Washout")

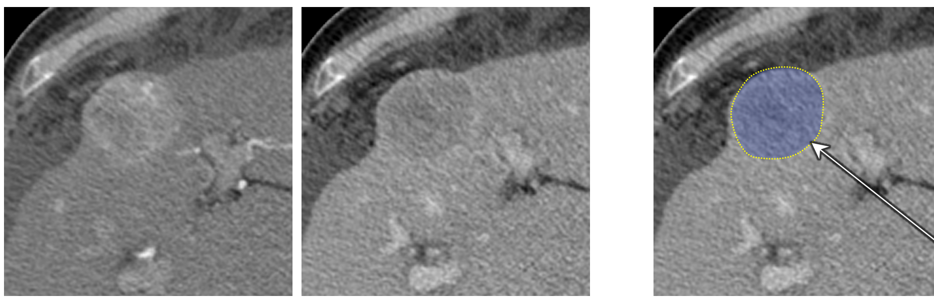
RADLEX ID: RID39486

Characterization (Cont'd)

"Washout" may be in whole:

AP | Postarterial ECP | ECP – Annotated

CT
27 mm
observation



Entire observation appears to wash out

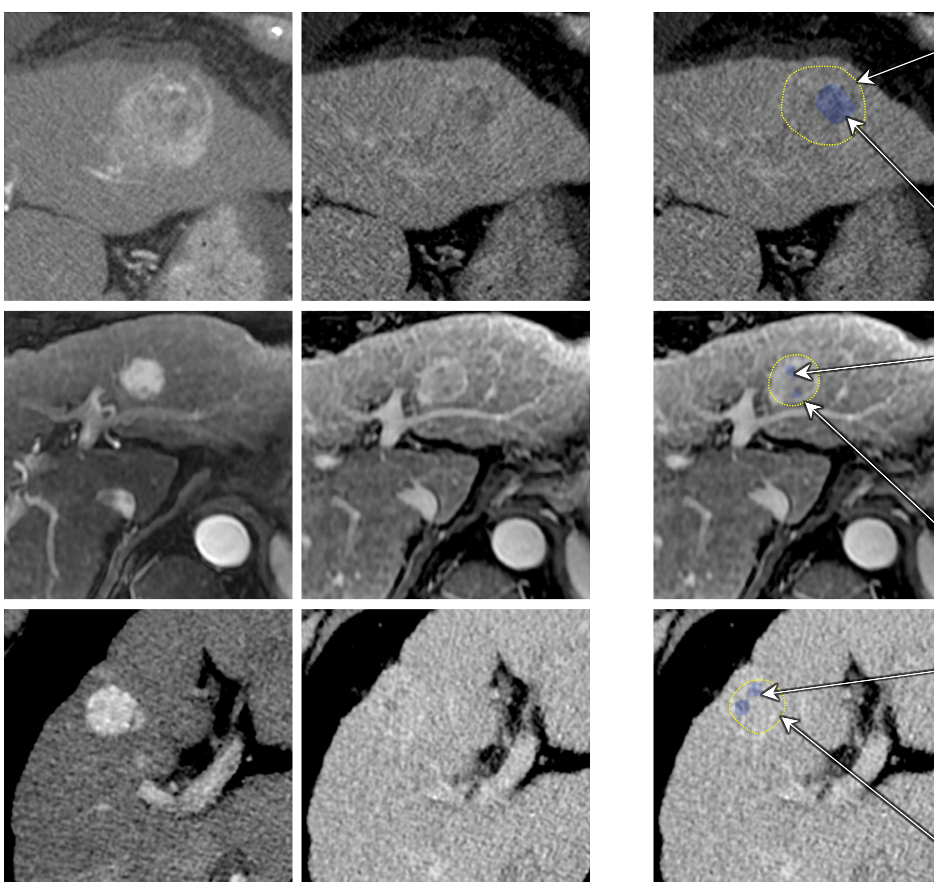
"Washout" may be in part:

AP | Postarterial ECP | ECP – Annotated

CT
31 mm
observation

MRI
20 mm
observation

CT
22 mm
observation



Part of observation showing "washout" (blue fill)

Entire observation (yellow outline)

Part of observation showing "washout" (blue fill)

Entire observation (yellow outline)

Part of observation showing "washout" (blue fill)

Entire observation (yellow outline)

Washout Appearance (“Washout”)

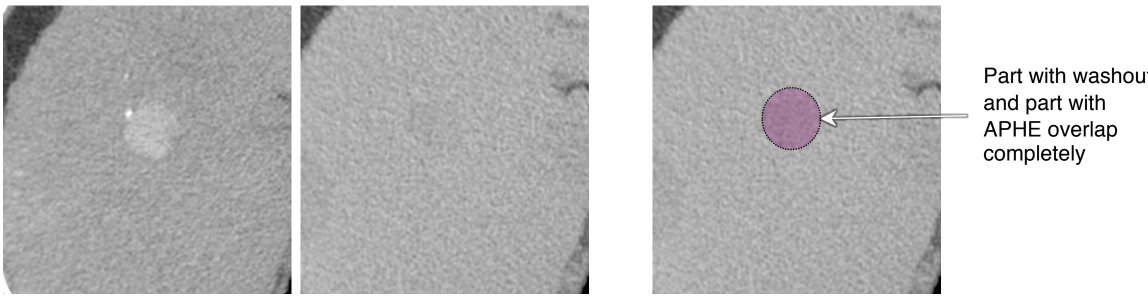
RADLEX ID: RID39486

Characterization (Cont’d)

The part with “washout” may overlap completely with the part with APHE

AP | Postarterial ECP | ECP – Annotated

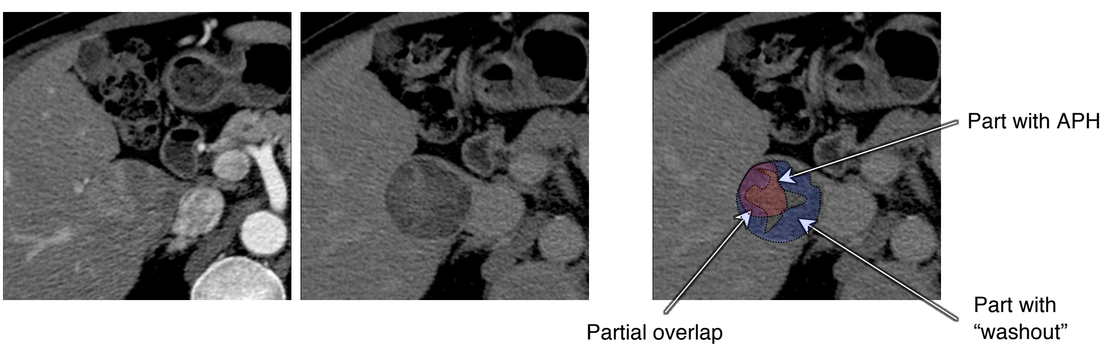
MRI, CT
23 mm
observation



The part with “washout” may overlap somewhat with the part with APHE

AP | Postarterial ECP | ECP – Annotated

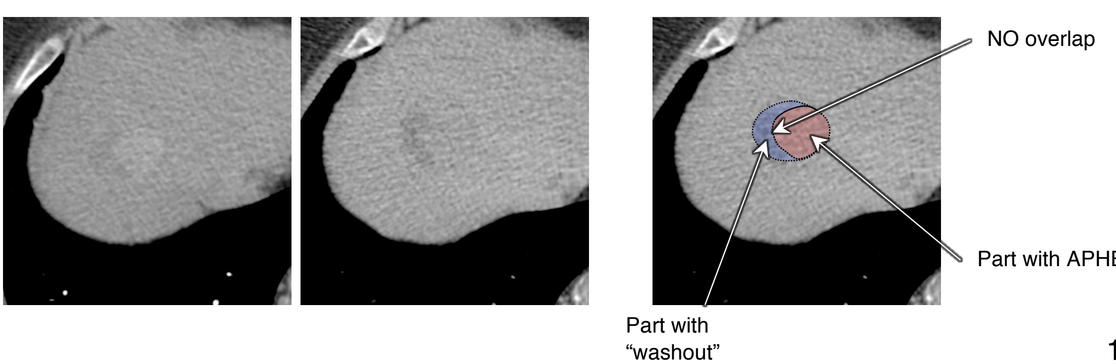
MRI, CT
29 mm
observation



The part with “washout” may not overlap at all with the part with APHE

AP | Postarterial ECP | ECP – Annotated

MRI, CT
33 mm
observation

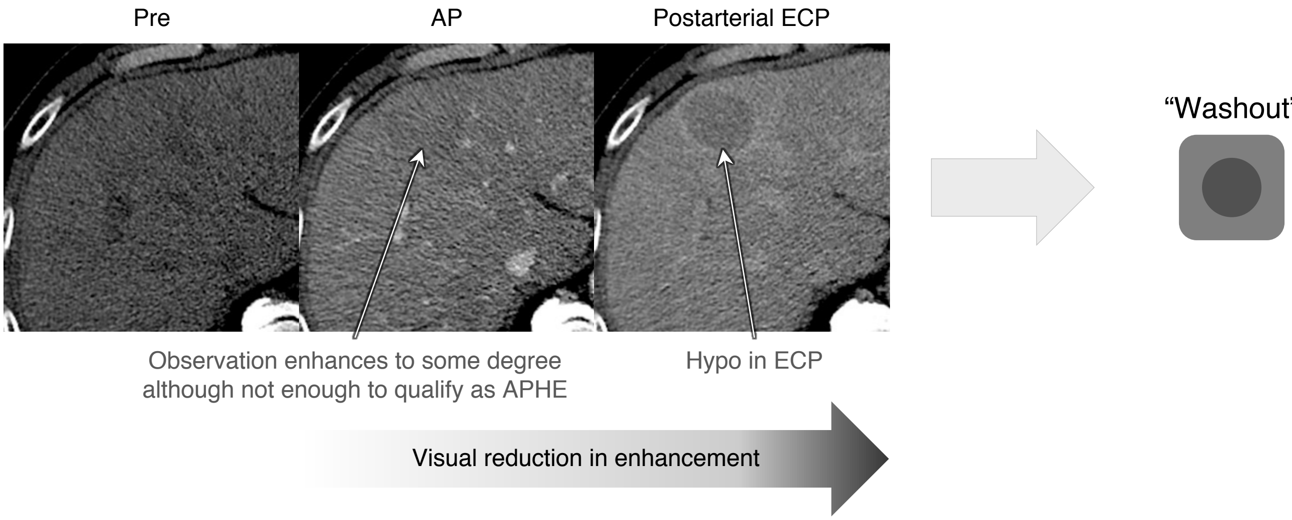


Washout Appearance (“Washout”)

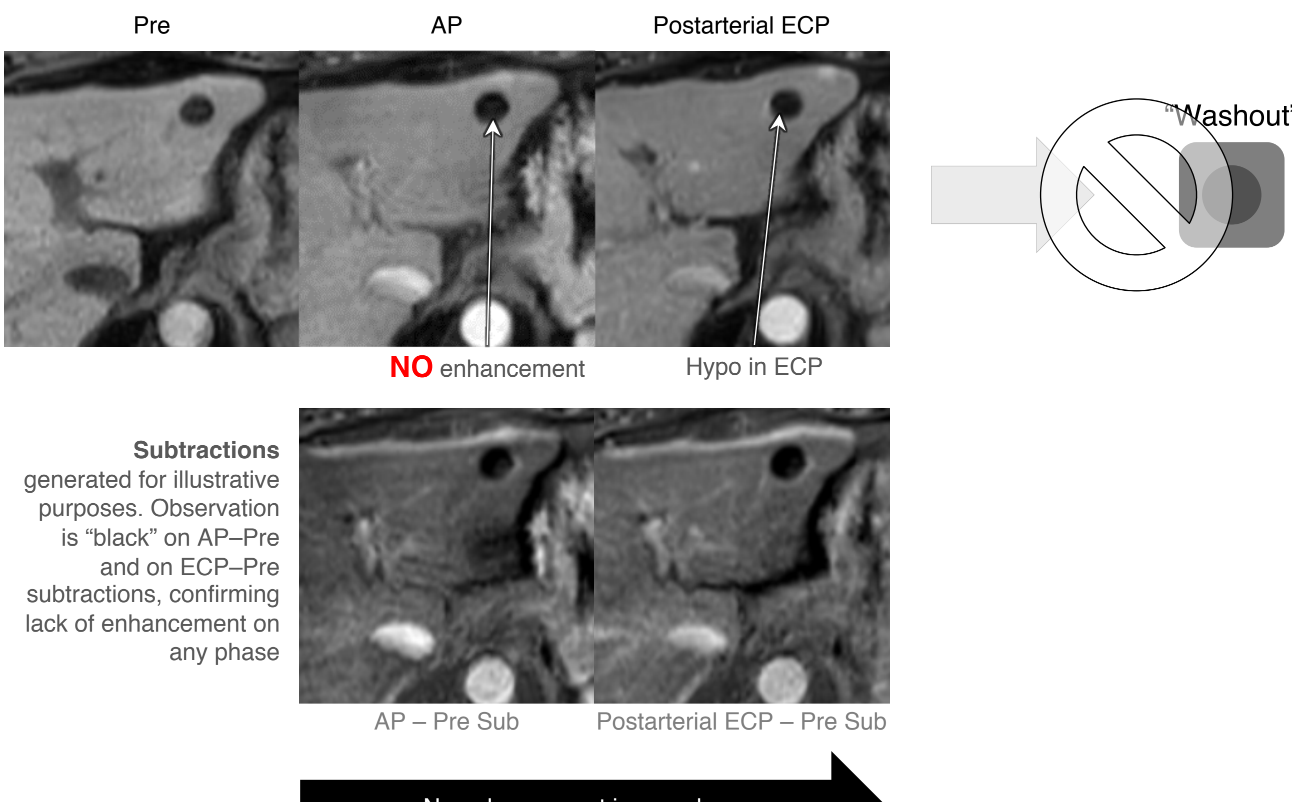
RADLEX ID: RID39486

Characterization (Cont’d)

The part with WO must enhance to some degree in earlier phases but need not show APHE.



As a corollary, observations without any enhancement (e.g., cysts) cannot have WO



Washout Appearance (“Washout”)

RADLEX ID: RID39486

Characterization (Cont’d)

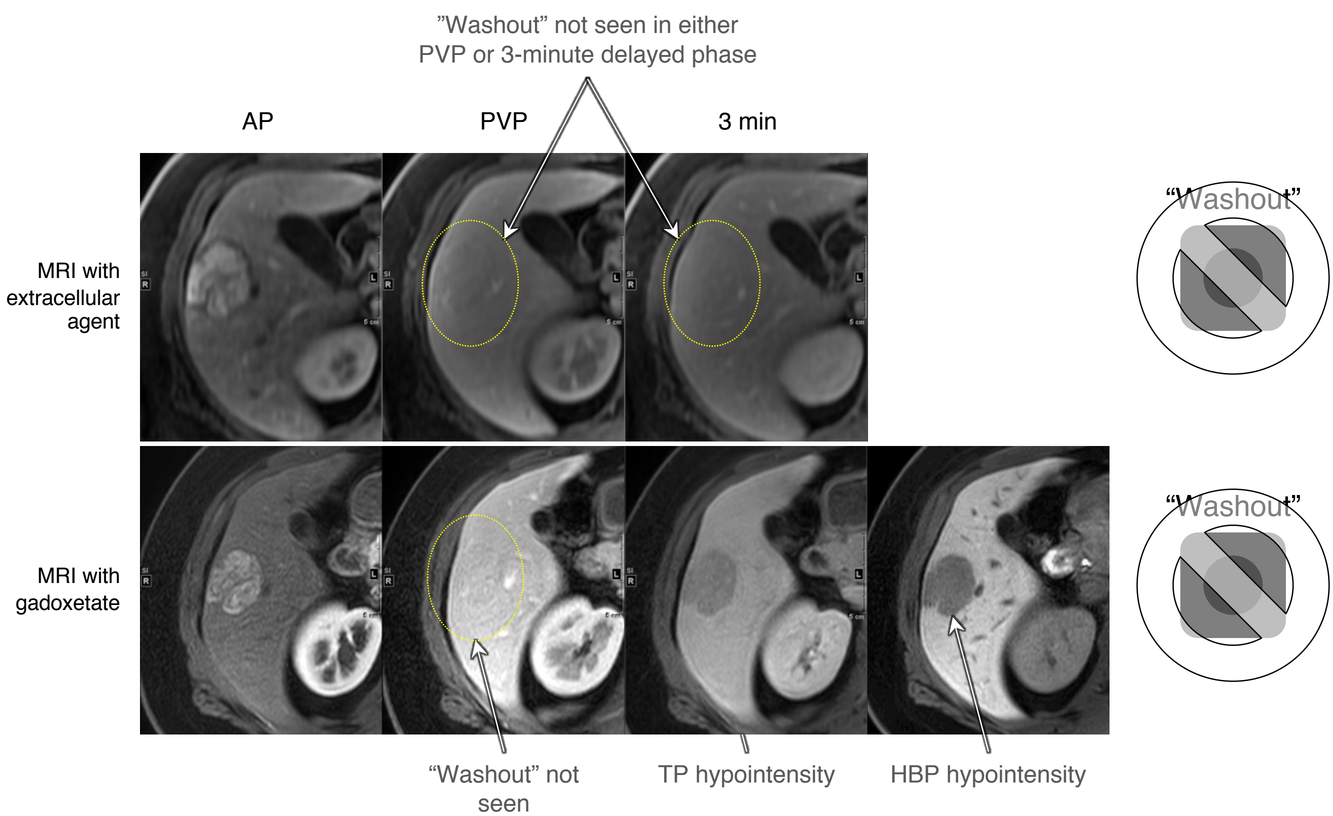
“Washout” should be characterized on extracellular phase images.

- For ECA and gadobenate: PVP, DP, or both.
- For gadoxetate: PVP only. Hypointensity in TP or HBP does not qualify as “washout”.

Rationale is illustrated by example below: 24 mm right-lobe mass with APHE.

With extracellular agent, mass is isointense in PVP and 3-min DP (i.e., mass shows fade, not “washout”)

With gadoxetate, same mass is isointense in PVP but hypointense in TP and HBP due to gadoxetate uptake by the parenchyma. Since mass has no “washout” in any phase with extracellular agent, the TP and HBP hypointensity should not be interpreted as “washout.”



- “Washout” must be assessed in PVP
- Neither TP nor HBP are used to assess “washout”

Washout Appearance ("Washout")

RADLEX ID: RID39486

Characterization (Cont'd)

"Washout" should be characterized on extracellular phase images.

- For ECA and gadobenate: PVP, DP, or both
- For gadoxetate: PVP only. Hypointensity in TP or HBP does not qualify as "washout".

Evidence

- TP hypointensity is not specific for HCC, and can be due to low OATP expression and/or high background liver enhancement, not "washout".
- Based on the current literature
  - APHE + "washout" in PVP : 93-100% specificity for HCC
  - APHE + 3 min TP hypointensity: 79-95% specificity for HCC
- DDx for TP hypointensity
  - HCC
  - Non-HCC malignancy: iCCA, cHCC-CCA, other
  - Some dysplastic nodules
  - Some hemangiomas
  - Confluent fibrosis

Washout Appearance ("Washout")

RADLEX ID: RID39486

Characterization (Cont'd)

"Washout" should be characterized on extracellular phase images.

- For ECA and gadobenate: PVP, DP, or both
- For gadoxetate: PVP only. Hypointensity in TP or HBP does not qualify as "washout".

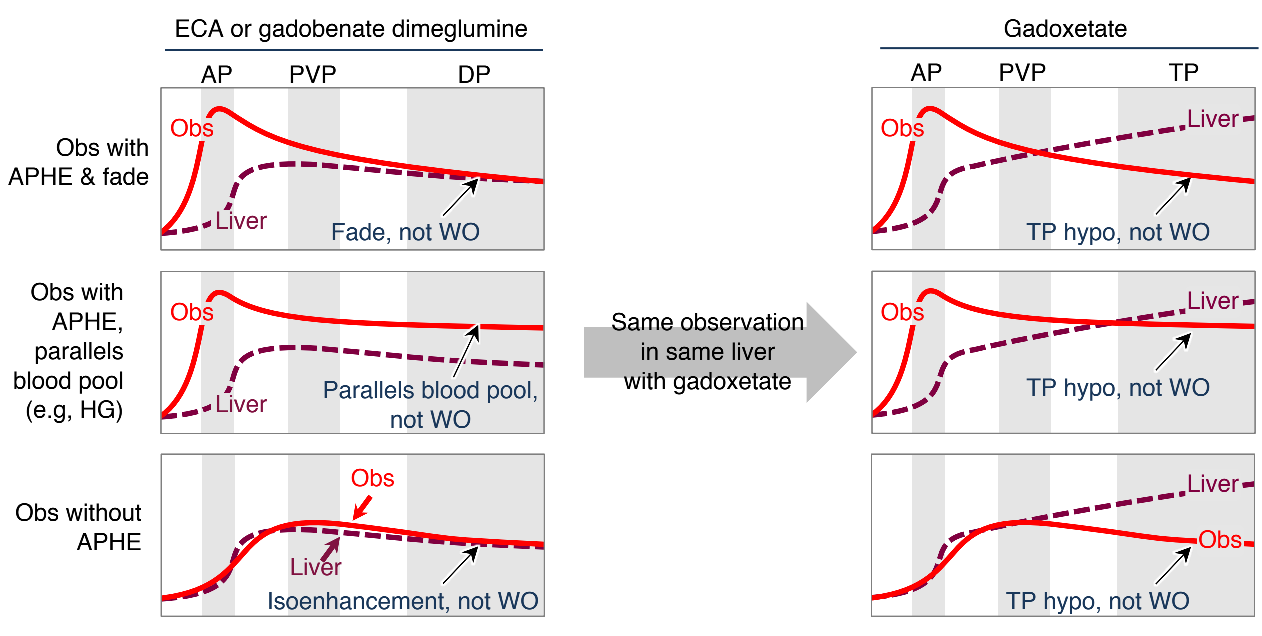
Time-intensity curves illustrating why transitional phase hypointensity ≠ "washout".

The time-intensity curves below show three observations (obs) without "washout" as characterized using ECA or gadobenate:

- Obs with APHE and fade
- Obs with APHE and parallels blood pool (e.g., hemangioma)
- Obs without APHE and near isoenhancement in all phases

Despite absence of "washout" with ECA or gadobenate, each observation appears hypointense to liver in the transitional phase on gadoxetate-enhanced MRI due to intracellular uptake of the agent by liver parenchyma, which causes the liver to be hyperenhanced.

Time-intensity curves



TP hypointensity of tumor is due to hyperenhancement of liver, not "washout"

Washout Appearance (“Washout”)

RADLEX ID: RID39486

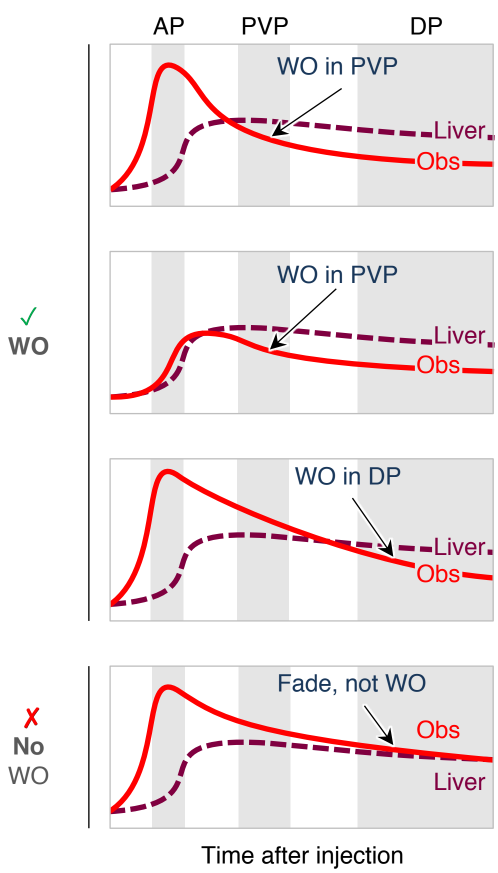
Characterization (Cont’d)

“Washout” should be characterized on extracellular phase images:

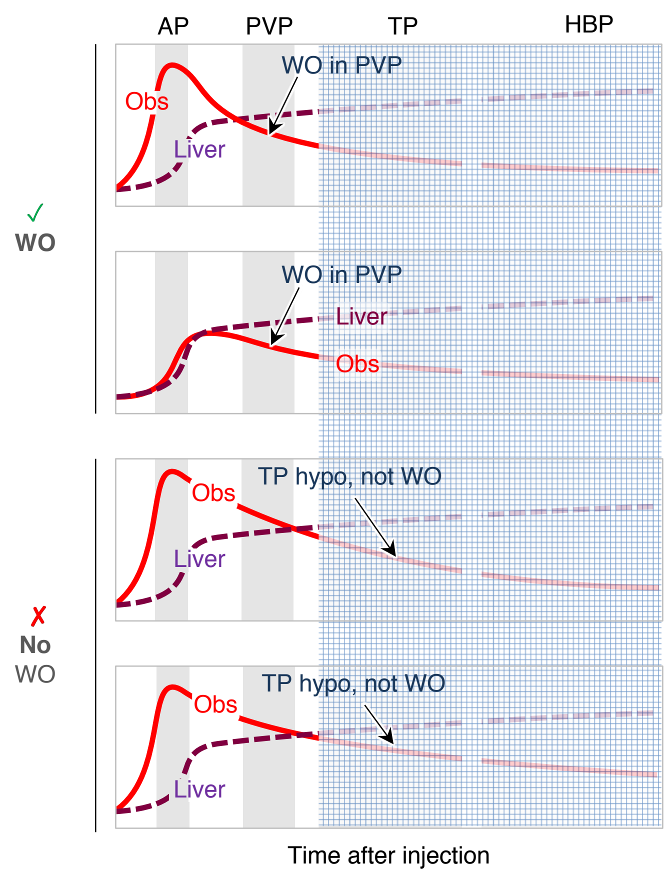
- For ECA and gadobenate: PVP, DP, or both
- For gadoxetate: PVP only. Hypointensity in TP or HBP does not qualify as “washout”.

Time-intensity curves illustrating appropriate characterization of “washout”

“Washout” (WO) with ECA or gadobenate



“Washout” (WO) with gadoxetate



- “Washout” must be assessed in PVP
- Neither TP nor HBP are used to assess “washout”

Washout Appearance (“Washout”)

RADLEX ID: RID39486

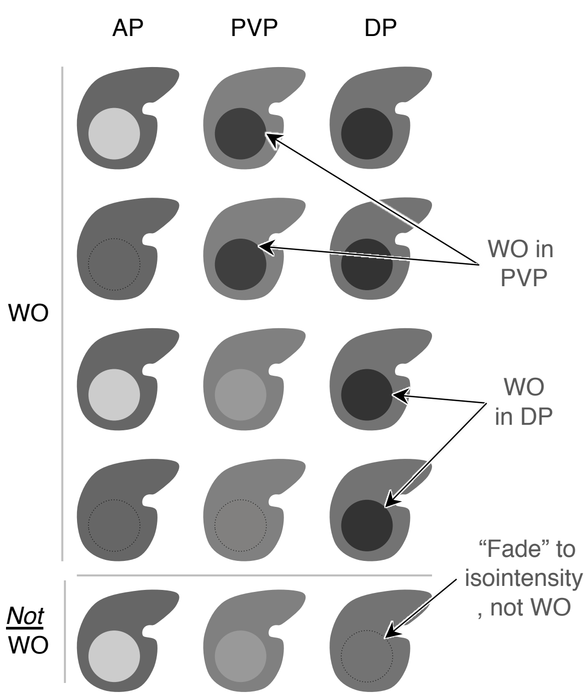
Characterization (Cont’d)

“Washout” should be characterized on extracellular phase images:

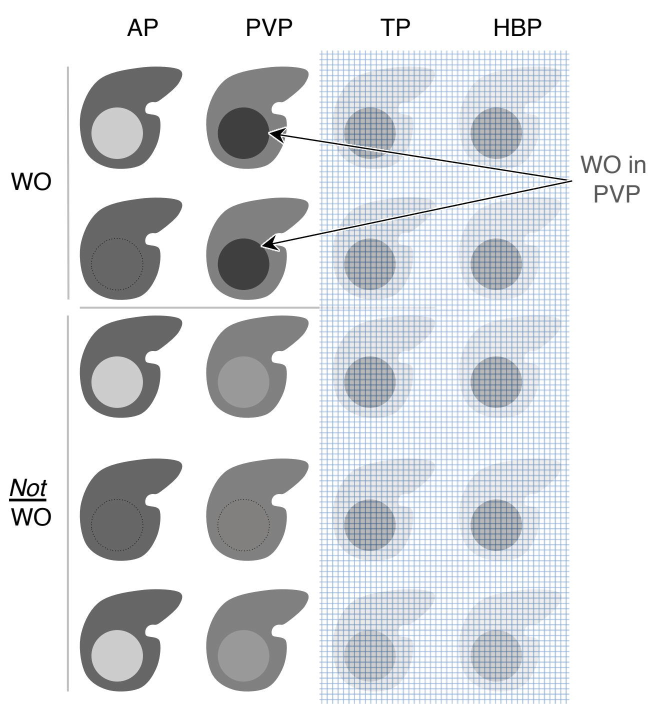
- For ECA and gadobenate: PVP, DP, or both
- For gadoxetate: PVP only. Hypointensity in TP or HBP does not qualify as “washout”.

Schematic diagrams illustrating appropriate characterization of “washout”

“Washout” (WO) with ECA or gadobenate



“Washout” (WO) with gadoxetate



- “Washout” must be assessed in PVP
- Neither TP nor HBP can be used to assess “washout”

Washout Appearance (“Washout”)

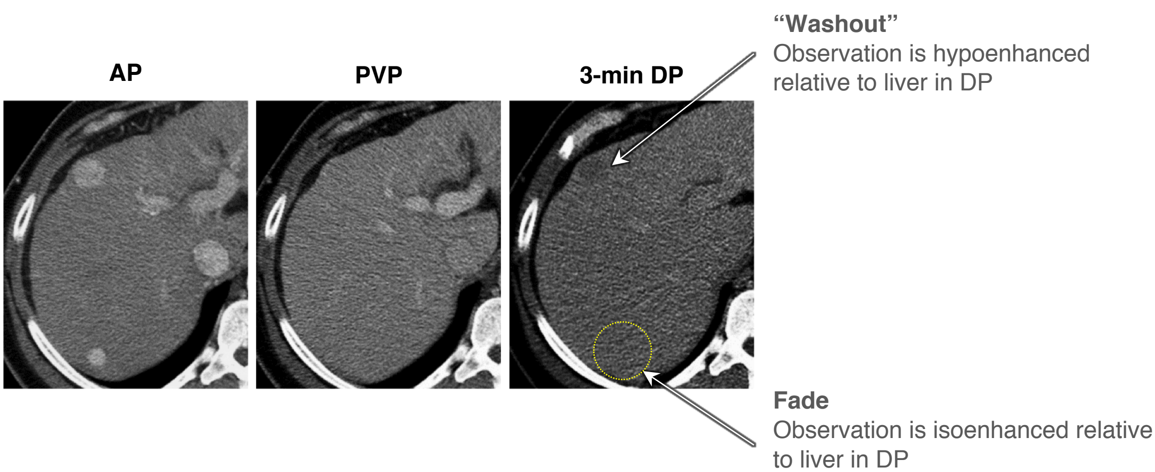
RADLEX ID: RID39486

Characterization (Cont’d)

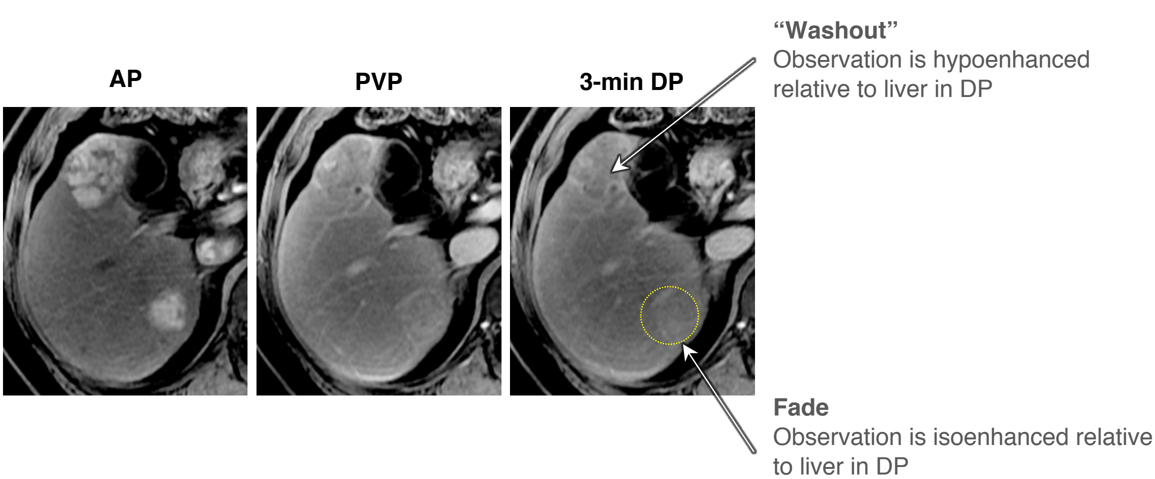
“Washout” and fade are not the same.

- Washout results in postarterial phase hypoenhancement
- Fade results in postarterial phase isoenhancement

Example: CT



Example: MRI



Washout Appearance ("Washout")

RADLEX ID: RID39486

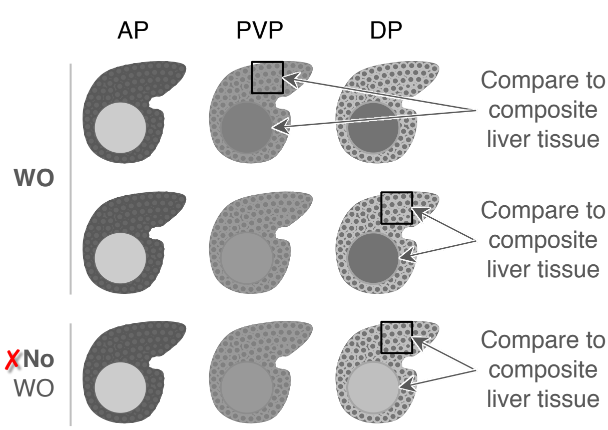
Characterization (Cont'd)

Compare attenuation or intensity of observation to adjacent liver parenchyma

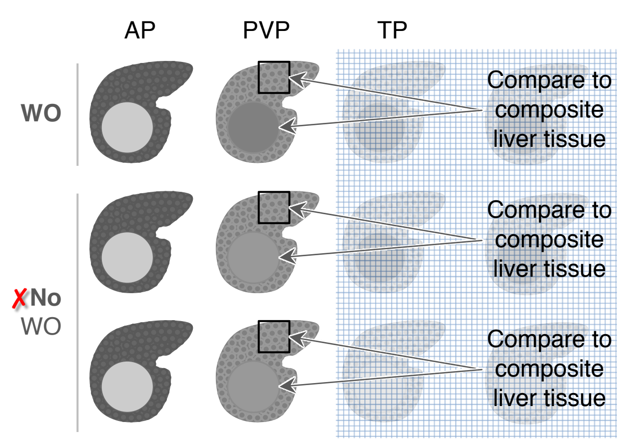
If the liver parenchyma visually consists of both nodules and fibrosis, then compare to composite liver tissue (i.e., a visual average of the nodules and fibrosis).

- **Rationale:**
  - There is no scientific evidence that comparison to background nodules in particular (as opposed to composite liver tissue) meaningfully improves specificity for HCC.
  - But requiring comparison to background nodules would increase interpretation complexity, may reduce sensitivity for HCC, and may increase reader variability.

"Washout" (WO) with ECA or gadobenate



"Washout" (WO) with gadoxetate



- "Washout" must be assessed in PVP
- Neither TP nor HBP can be used to assess "washout"

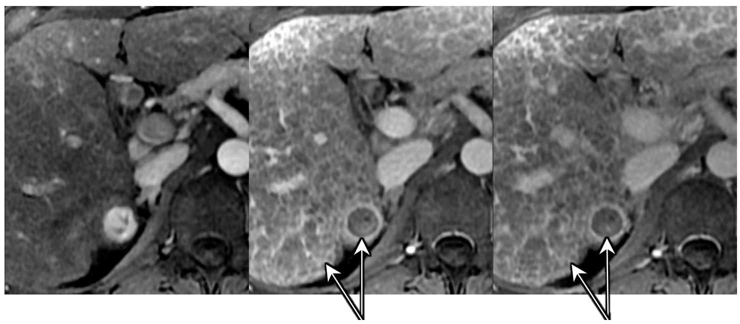
Washout Appearance ("Washout")

RADLEX ID: RID39486

Characterization (Cont'd)

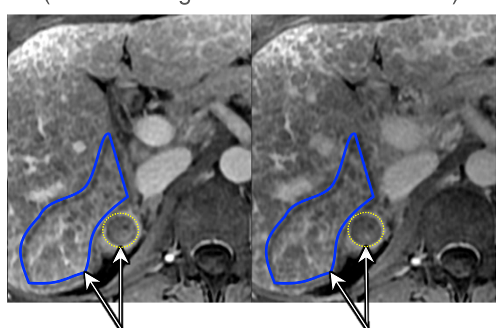
Background nodules and fibrosis are sometimes visible at MRI. If so, compare observation to composite liver tissue

AP PVP 3 min



Compare to composite liver tissue
(visual average of nodules and fibrosis)

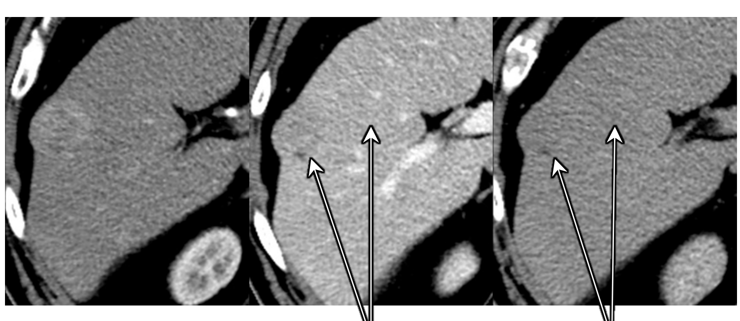
Annotated



Compare to composite liver tissue
(visual average of nodules and fibrosis)

Background nodules and fibrosis are rarely discernible on CT, so "washout" assessment tends to be simpler.

AP PVP 3 min



Compare to adjacent liver.
Note that fibrosis and nodules are not discernible

Washout Appearance ("Washout")

RADLEX ID: RID39486

Characterization (Cont'd)

Use of subtraction images

For enhancing observations that are hyperintense on precontrast and in the postarterial extracellular phase (ECP), assessment of washout appearance can be challenging. For such observations and with care, subtraction images (subs) may be used to assess washout appearance if and only if the precontrast images and the postarterial ECP images are adequately co-registered **AND** acquired with identical technique.

With caution, subtractions may be used to characterize "washout" when ECP/pre images are misregistered if amount of misregistration is small relative to region(s) being assessed for "washout".

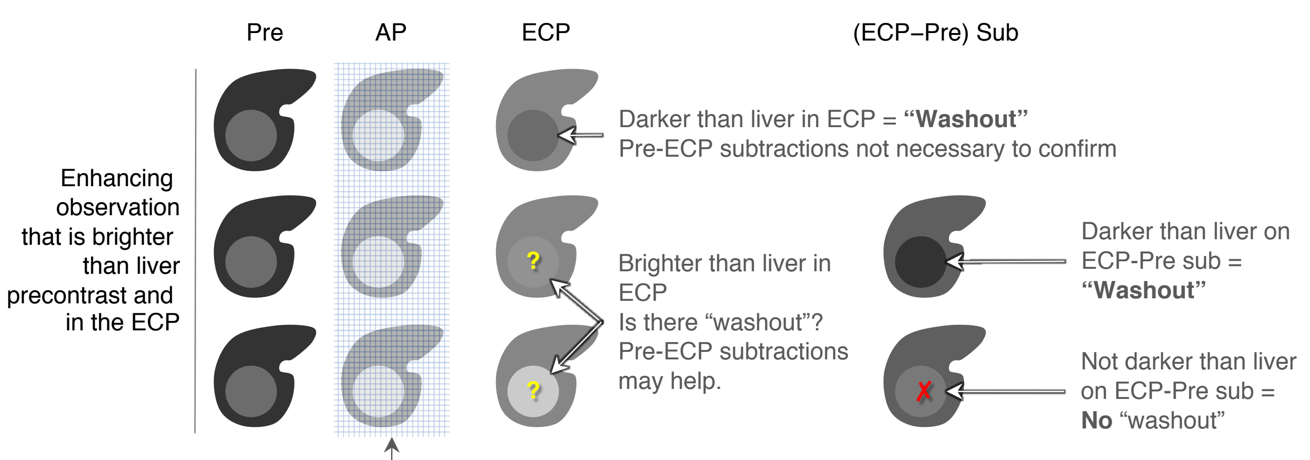
See *Chapter 12, page 24* for definition of and instructions for performing subtractions.

Interpretation

Step 1. Verify co-registration for each observation. If images for a particular observation are not co-registered, be cautious in using subtractions to characterize "washout" for that observation.

Step 2. Verify that the observation enhances unequivocally in the arterial phases. Although APHE is not required to apply subtractions, some degree of enhancement must be present.

Step 3. Compare intensity of observation relative to liver on (ECP−Pre) sub. Unequivocal hypointensity of observation relative to liver on the sub is interpreted as "washout".



AP images are not used in creating "washout" subs but they should be reviewed to confirm that observation enhances

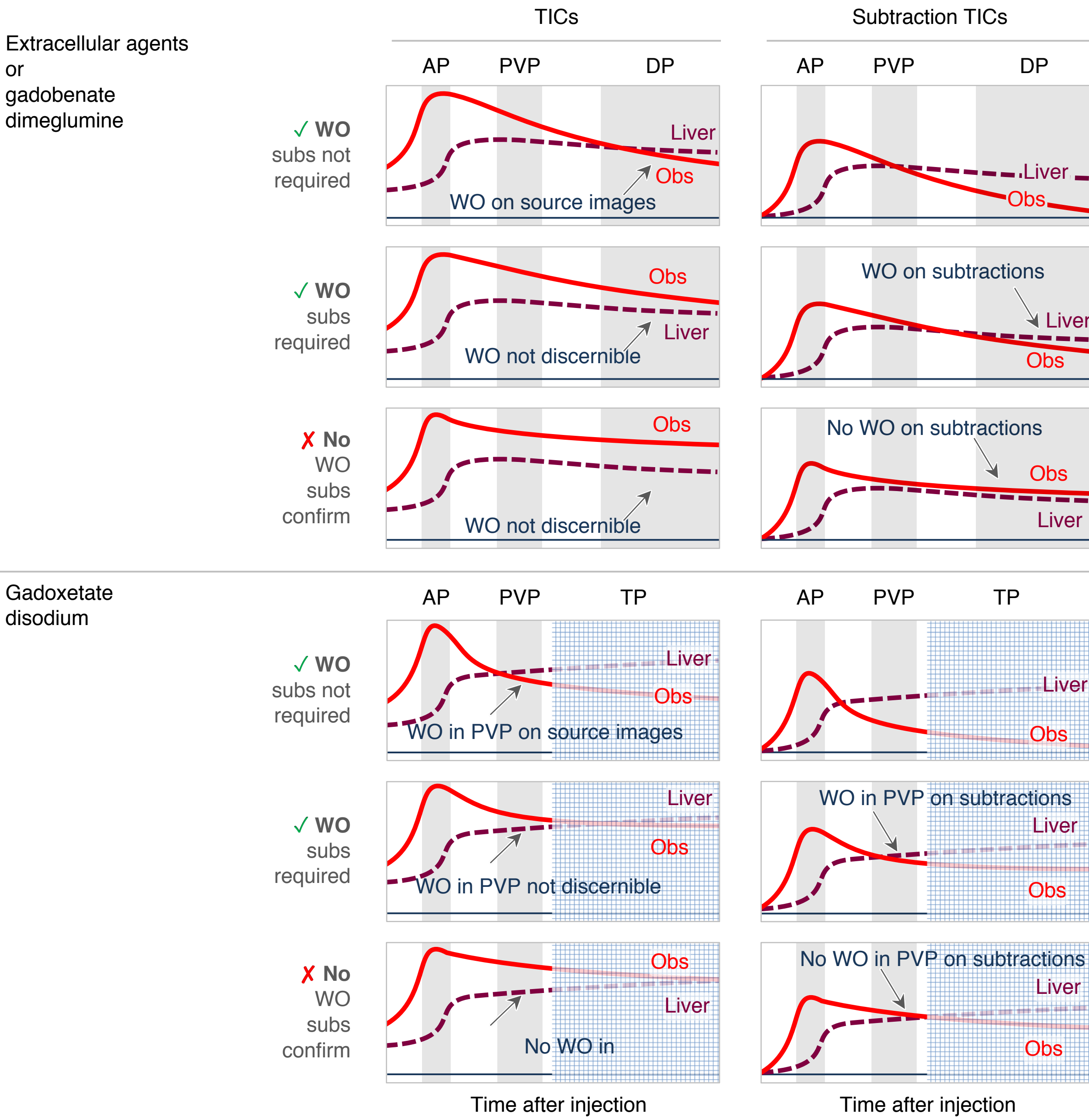
Washout Appearance (“Washout”)

RADLEX ID: RID39486

Characterization (Cont’d)

Use of subtractions (Cont’d)

Time-intensity curves (TICs) below illustrate use of subtractions to characterize “washout” of observation (obs) that is brighter than liver precontrast



- “Washout” must be assessed in PVP
- Neither TP nor HBP can be used to assess “washout”

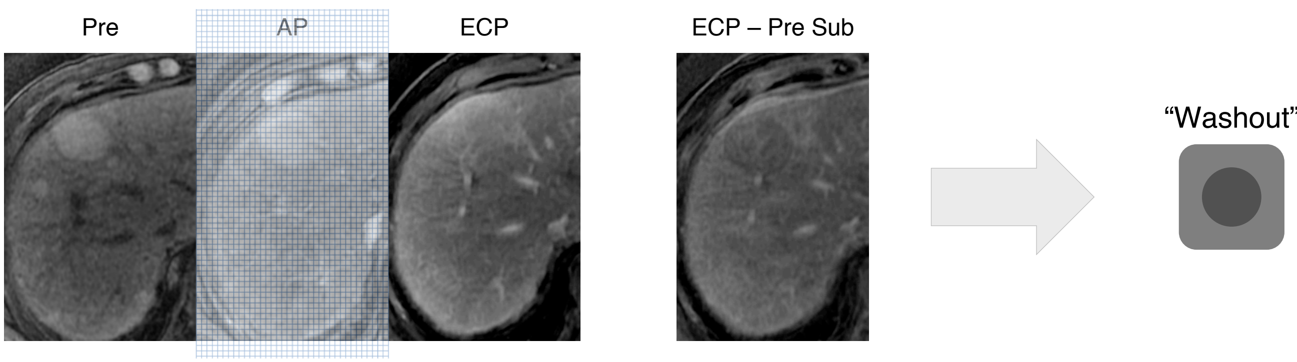
Washout Appearance (“Washout”)

RADLEX ID: RID39486

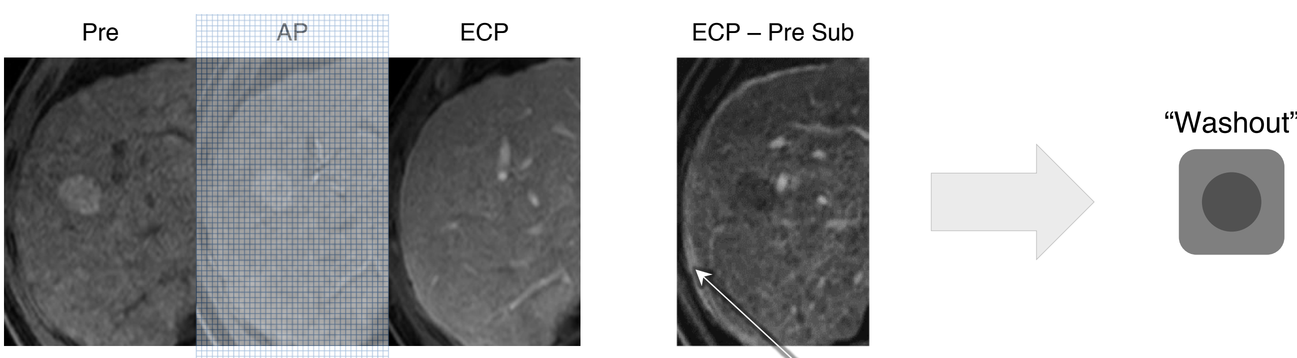
Characterization (Cont'd)

Subtractions

ECP – Pre subtractions may be used to characterize WO if observation is intrinsically T1 hyperintense and images are co-registered



With caution, the ECP – Pre subtractions may be used to characterize WO if observation is intrinsically T1 hyperintense and images are imperfectly registered co-registered



Note subtraction artifacts due to imperfect registration

AP images are not used in creating “washout” subs but they should be reviewed to confirm that observation enhances

Washout Appearance (“Washout”)

RADLEX ID: RID39486

Characterization (Cont'd)

If unsure

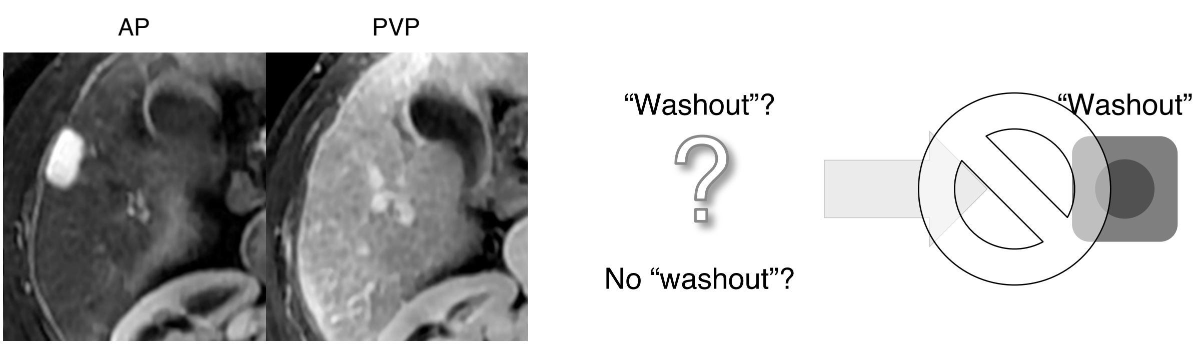
If unsure about “washout” vs no “washout”, do not characterize as “washout”

- *Rationale: LI-RADS imaging features are characterized as present only if there is certainty*

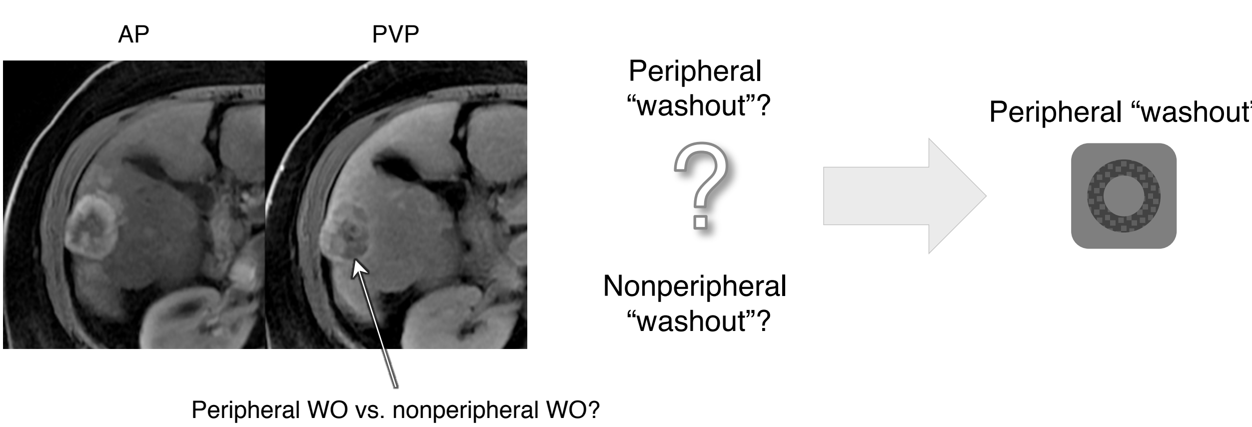
If unsure about peripheral “washout” vs nonperipheral “washout”, characterize as peripheral “washout”

- *Rationale: provides low threshold for alerting referrer to possibility of non-HCC malignancy*

Example: “washout” vs no “washout” , characterize as no “washout”



Example: peripheral “washout” vs nonperipheral “washout”, characterize as peripheral “washout”



Washout Appearance (“Washout”)

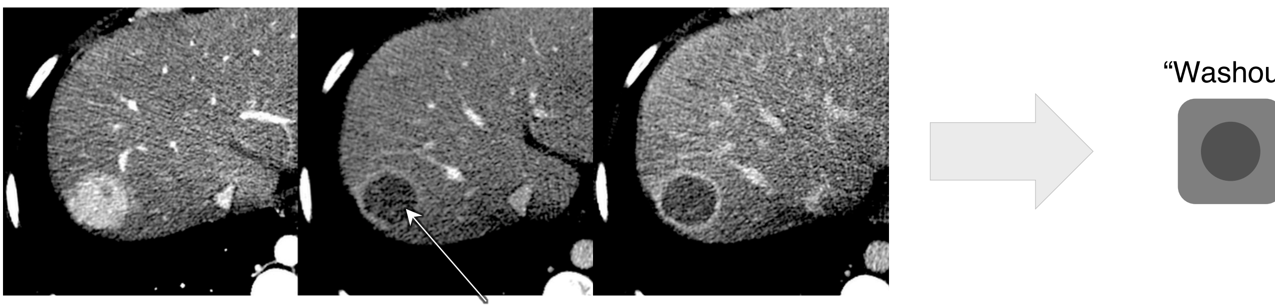
RADLEX ID: RID39486

Pitfalls & practical considerations

For CT with extracellular agents

Do: Characterize hyper (AP) → hypo (PVP) as “washout”

AP PVP DP



Hypo in PVP

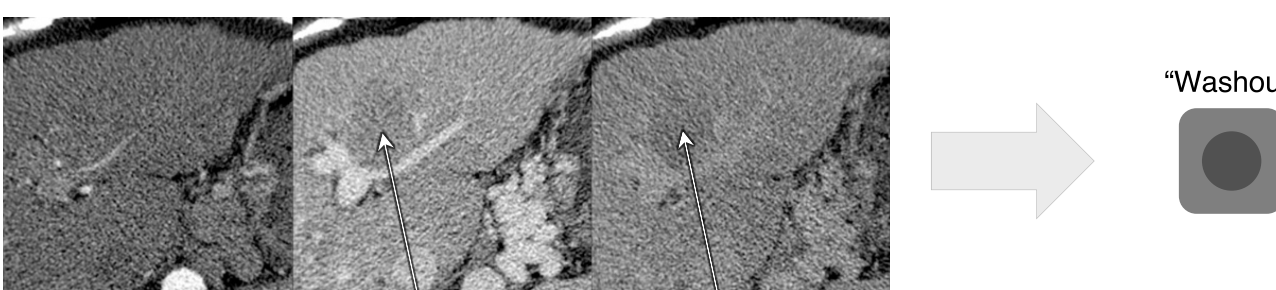
Do: Characterize hyper (AP) → iso (PVP) → hypo (DP) as “washout”

AP PVP DP

Hypo in DP

Do: Characterize iso (AP) → hypo (PVP) and/or hypo (DP) as “washout”

AP PVP DP



Hypo in PVP Hypo in DP

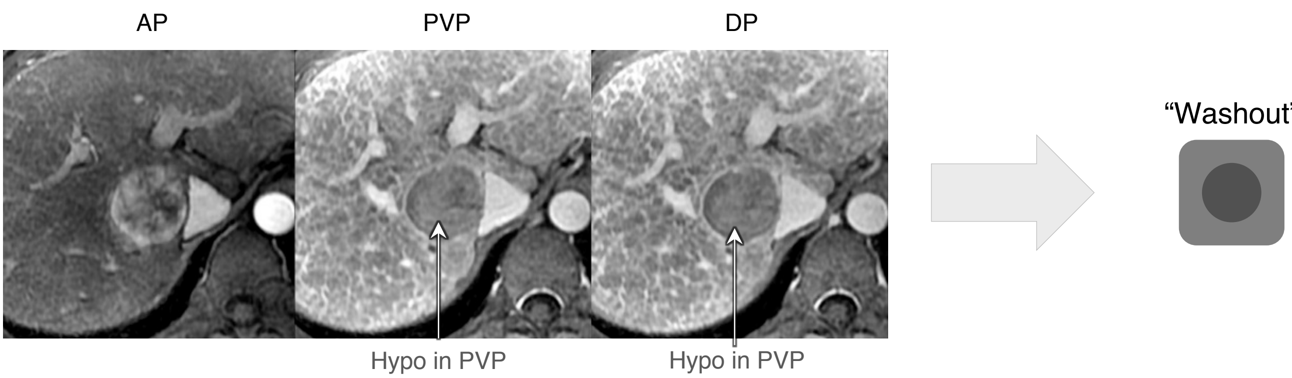
Washout Appearance ("Washout")

RADLEX ID: RID39486

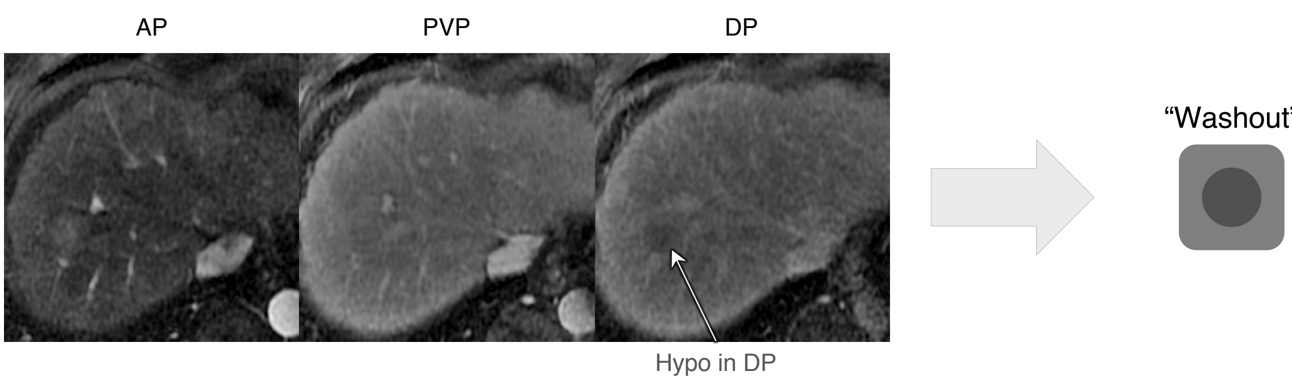
Pitfalls & practical considerations (Cont'd)

For MRI with extracellular agents or gadobenate

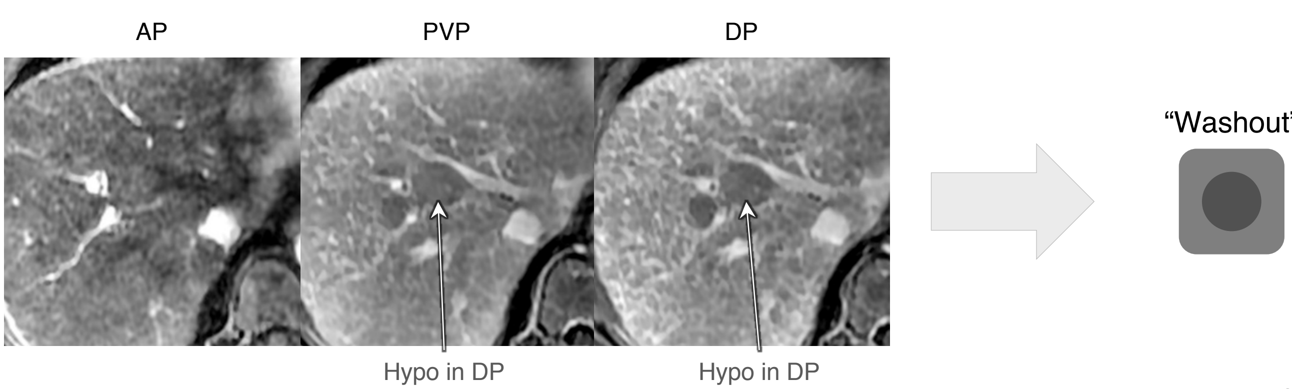
Do: Characterize hyper (AP) → hypo (PVP) as "washout"



Do: Characterize hyper (AP) → iso (PVP) → hypo (DP) as "washout"



Do: Characterize iso (AP) → hypo (PVP) and/or hypo (DP) as "washout"



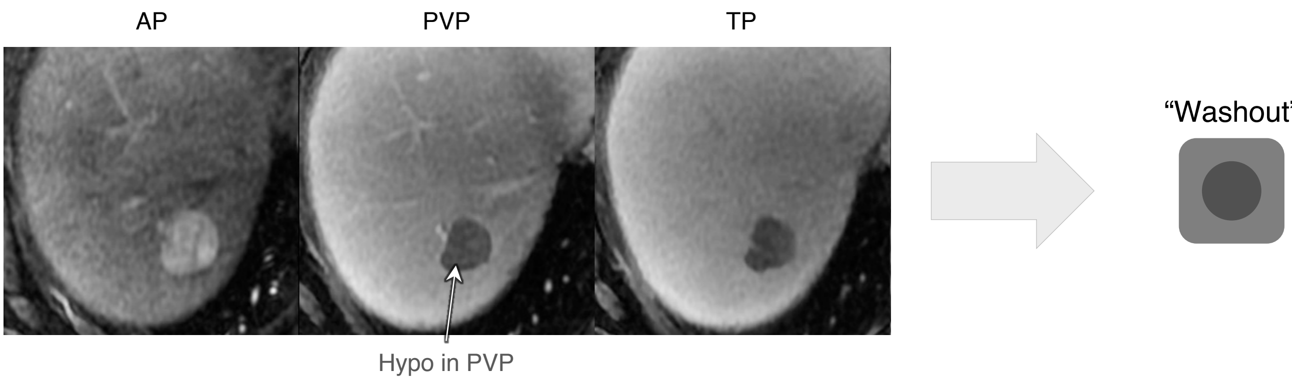
Washout Appearance (“Washout”)

RADLEX ID: RID39486

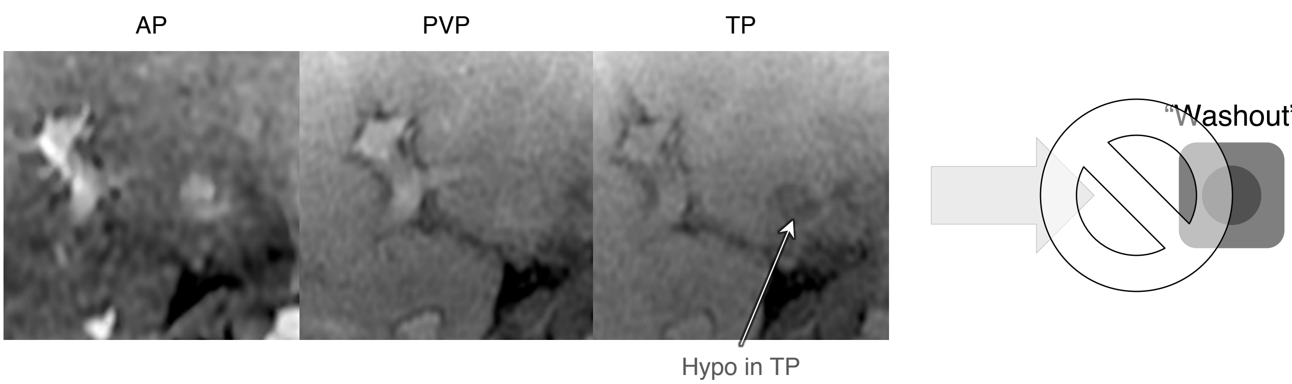
Pitfalls & practical considerations (Cont’d)

For MRI with gadoxetate disodium

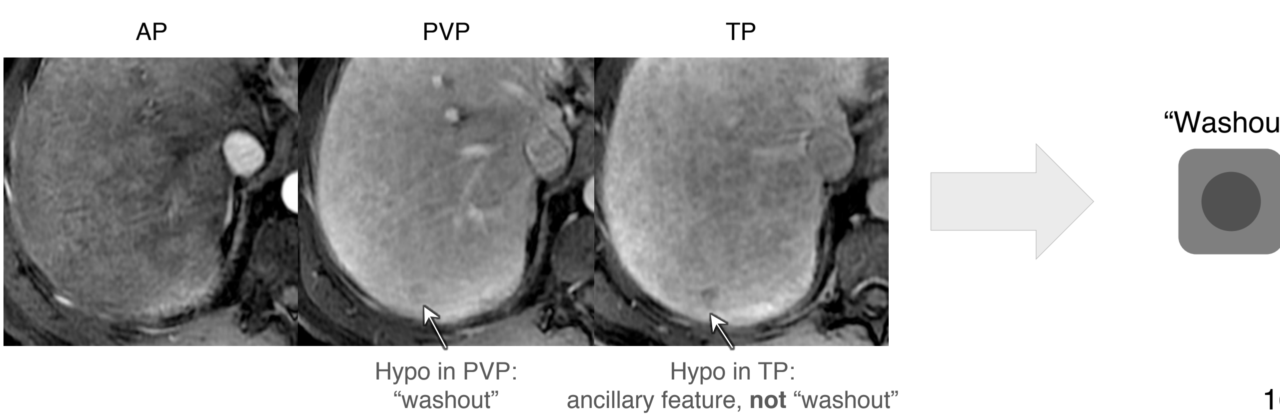
Do: Characterize hyper (AP) → hypo (PVP) as “washout”



Do NOT: Characterize hyper (AP) → iso (PVP) → hypo (TP) as “washout”



Do: Characterize iso (AP) → hypo (PVP) as “washout”



Washout Appearance (“Washout”)

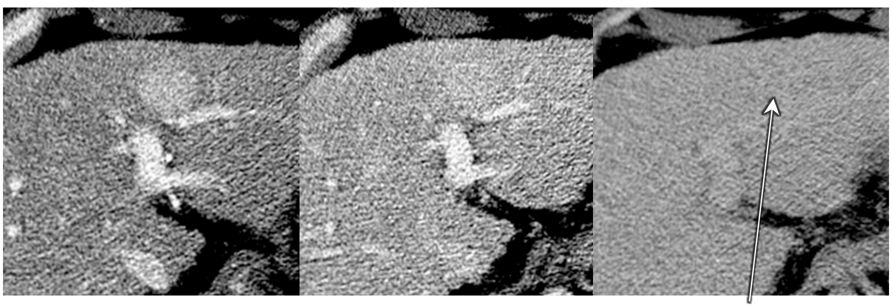
RADLEX ID: RID39486

Pitfalls & practical considerations (Cont’d)

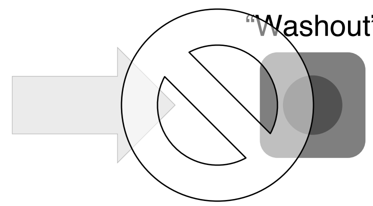
For extracellular agents or gadobenate

Do not: Characterize hyper (AP) → hyper (PVP) → iso (DP) as “washout”

AP PVP DP

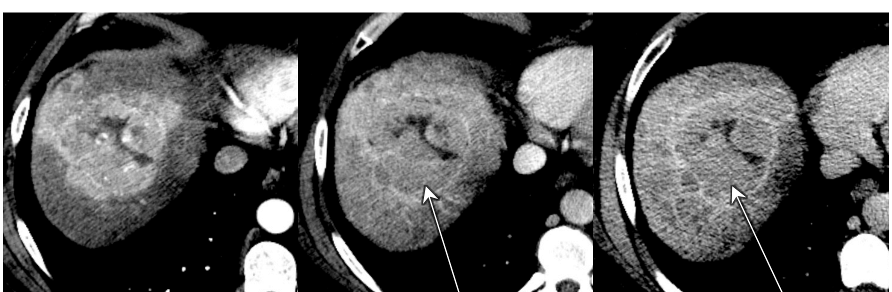


Iso in DP

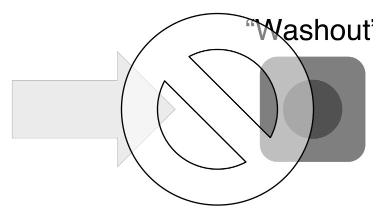


Do not: Characterize hyper (AP) → iso (PVP) → iso (DP) as “washout”

AP PVP DP



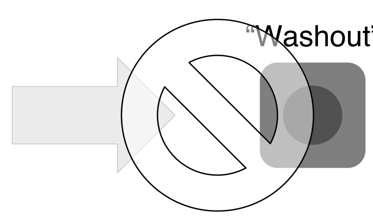
Isp in PVP Isp in DP



Do not: Characterize hypo (AP) → hypo (PVP) → hypo (DP) as “washout”

AP PVP DP

hypo in AP hypo in PVP hypo in DP



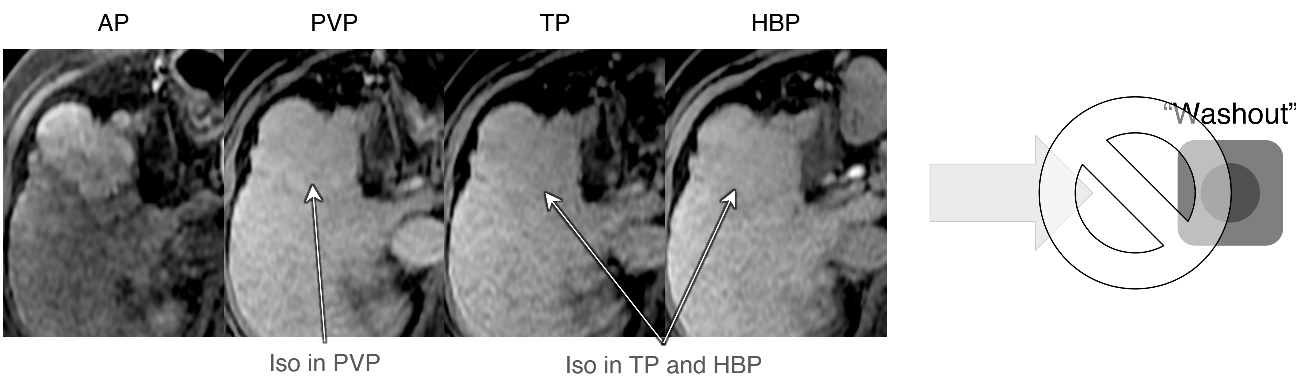
Washout Appearance (“Washout”)

RADLEX ID: RID39486

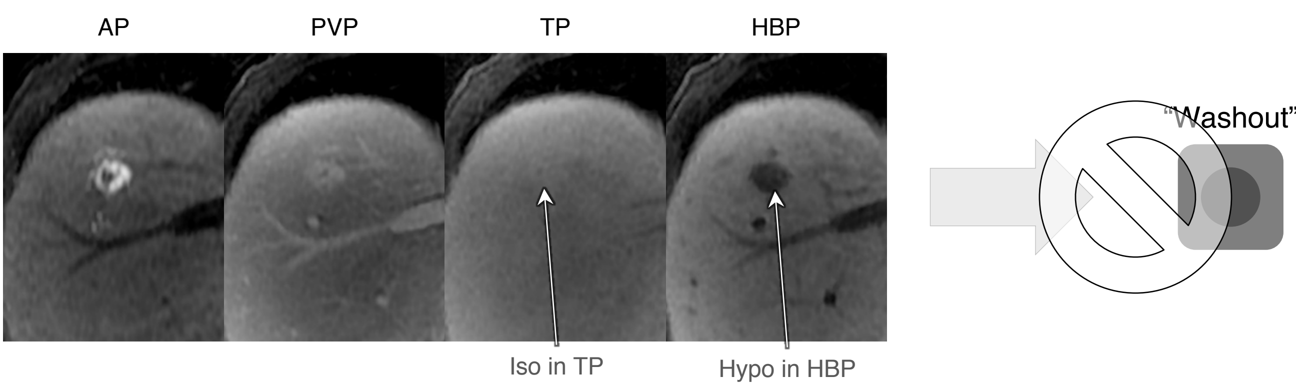
Pitfalls & practical considerations (Cont’d)

For gadoxetate disodium

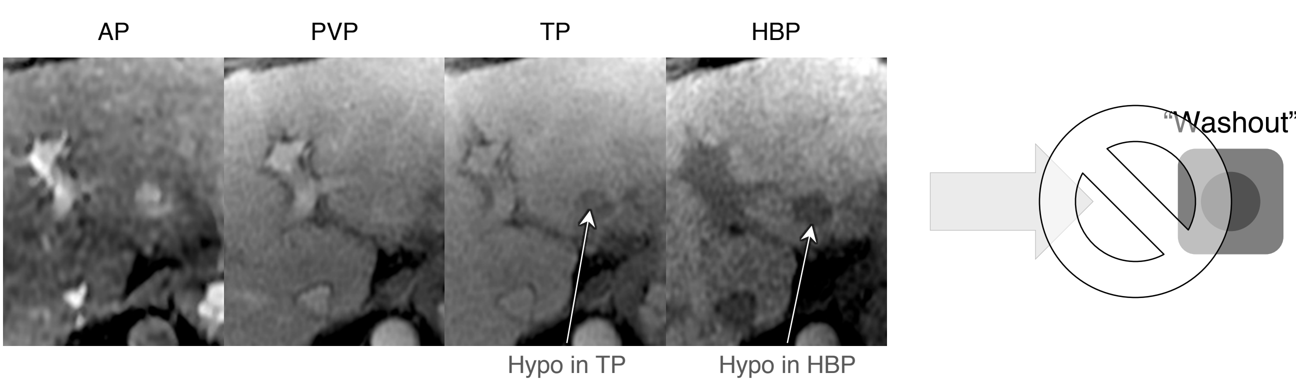
Do not: Characterize hyper (AP) → iso (PVP) → iso (TP) → iso (HBP) as “washout”



Do not: Characterize hyper (AP) → hyper (PVP) → iso (TP) → hypo (HBP) as “washout”



Do not: Characterize hyper (AP) → iso (PVP) → hypo (TP) → hypo (HBP) as “washout”



Washout Appearance (“Washout”)

RADLEX ID: RID39486

Pitfalls & practical considerations (Cont’d)

“Washout” pitfalls are divided into three categories:

- Optical illusion pitfalls
- Misinterpretation pitfalls
- Detection pitfalls

Optical illusion pitfalls refer to the false visual perception of “washout” when there is no actual washout.

The false perception of “washout” may be due to:

- Enhancing fibrosis, page 16-116
- Enhancing “capsule”, page 16-115

Misinterpretation pitfalls refer to the misinterpretation of intrinsic hypointensity as “washout”.

For example, fat or iron in an observation may create the appearance of WO on MRI when there is none because such observations tend to be dark.

Detection pitfalls refers to situations in which “washout” is present but difficult to recognize.

Difficulties in recognizing “washout” may be due to:

- Technical factors
  - Modality: Washout appearance may be more difficult to detect on CT than MRI due to the greater soft tissue contrast sensitivity of MRI. Page 16-118
  - Phase: Washout appearance may be more difficult to detect in PVP than in DP. Some HCCs appear to wash out only in the DP. Page 16-119
  - Contrast agent: Washout appearance may be more difficult to detect on gadoxetate-MRI than extracellular agent-MRI. Page 16-120
- Appearance of background liver. “Washout” may be difficult to recognize if the background liver is darker than normal.
  - This may occur if the liver is steatotic (CT or MRI) or iron overloaded (MRI). Page 16-121
- Intrinsic brightness of the observation. Washout may be difficult to recognize if the observation is intrinsically bright, i.e., hyperattenuating (CT) or T1 hyperintense (MRI). Page 16-123

Washout Appearance (“Washout”)

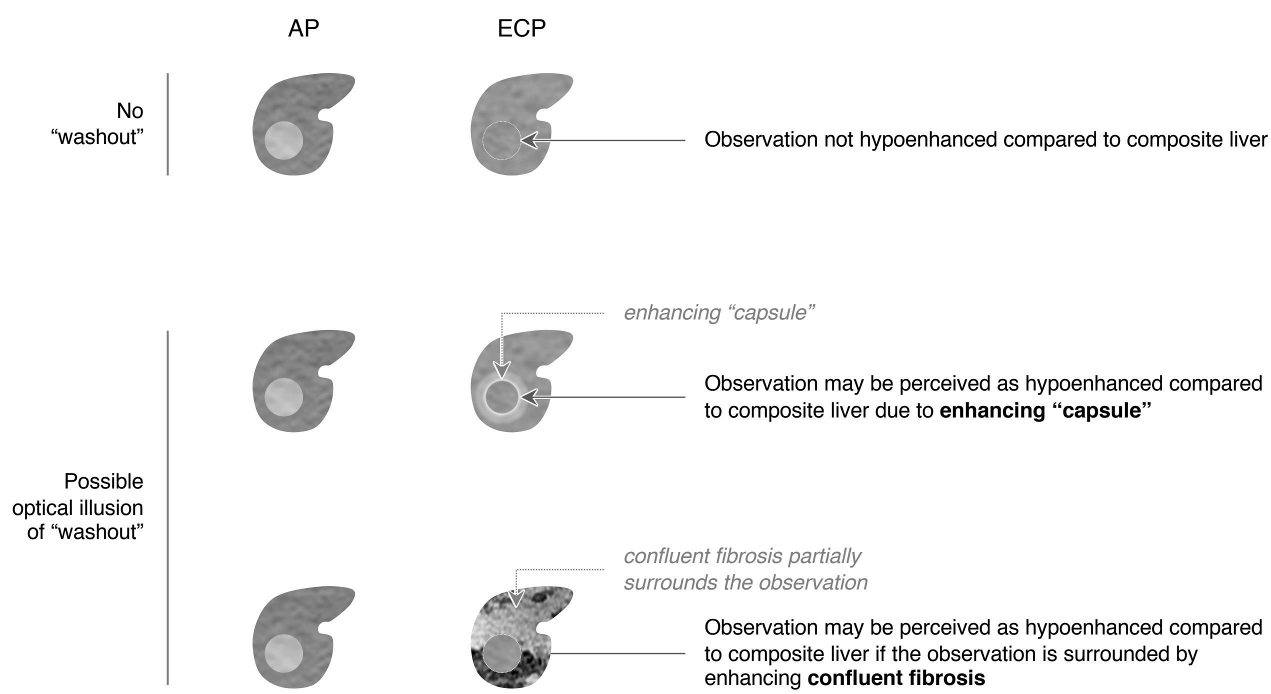
RADLEX ID: RID39486

Pitfalls & practical considerations (Cont’d)

Optical illusion pitfalls

Washout appearance may be falsely perceived due to

- Enhancing confluent fibrosis
- Enhancing “capsule”



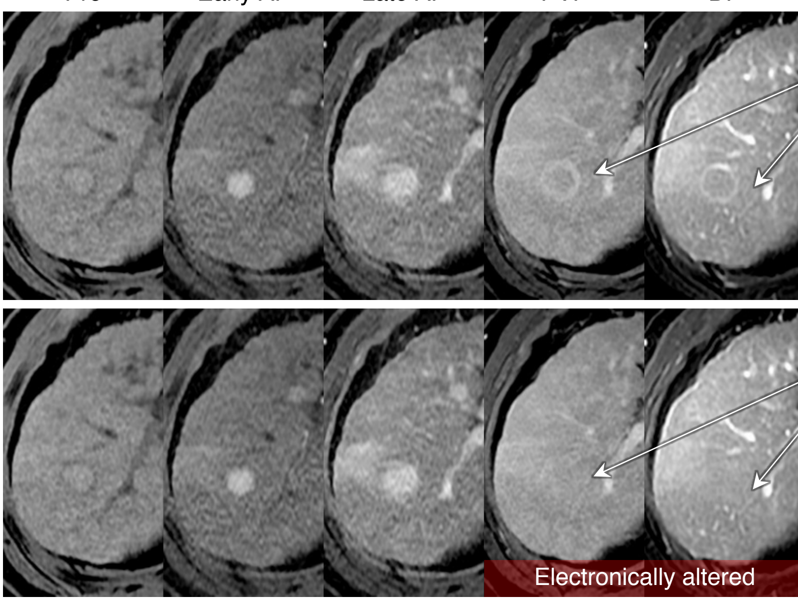
Washout Appearance ("Washout")

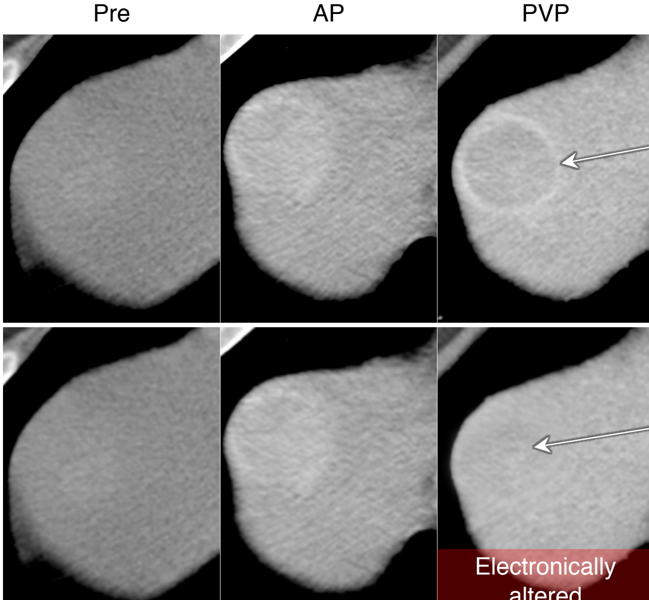
RADLEX ID: RID39486

Pitfalls & practical considerations (Cont'd)

Optical illusion pitfalls

Do not: characterize as "washout" if the perceived "washout" is plausibly an optical illusion related to observation **"capsule"**





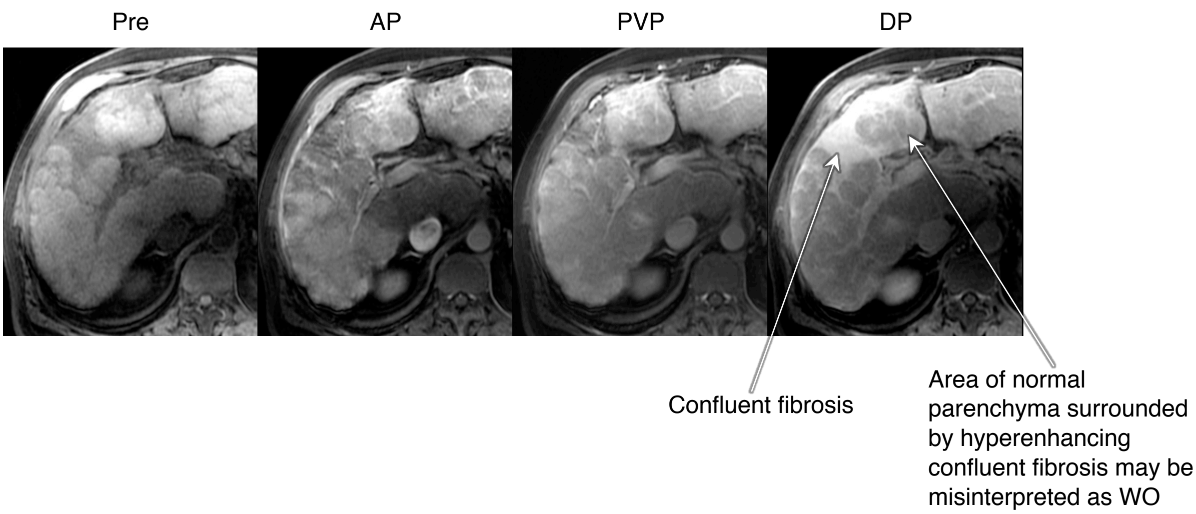
Washout Appearance ("Washout")

RADLEX ID: RID39486

Pitfalls & practical considerations (Cont'd)

Optical illusion pitfalls

Do not: characterize as "washout" if the perceived "washout" is plausibly an optical illusion related to periobservation **confluent fibrosis**



Washout Appearance (“Washout”)

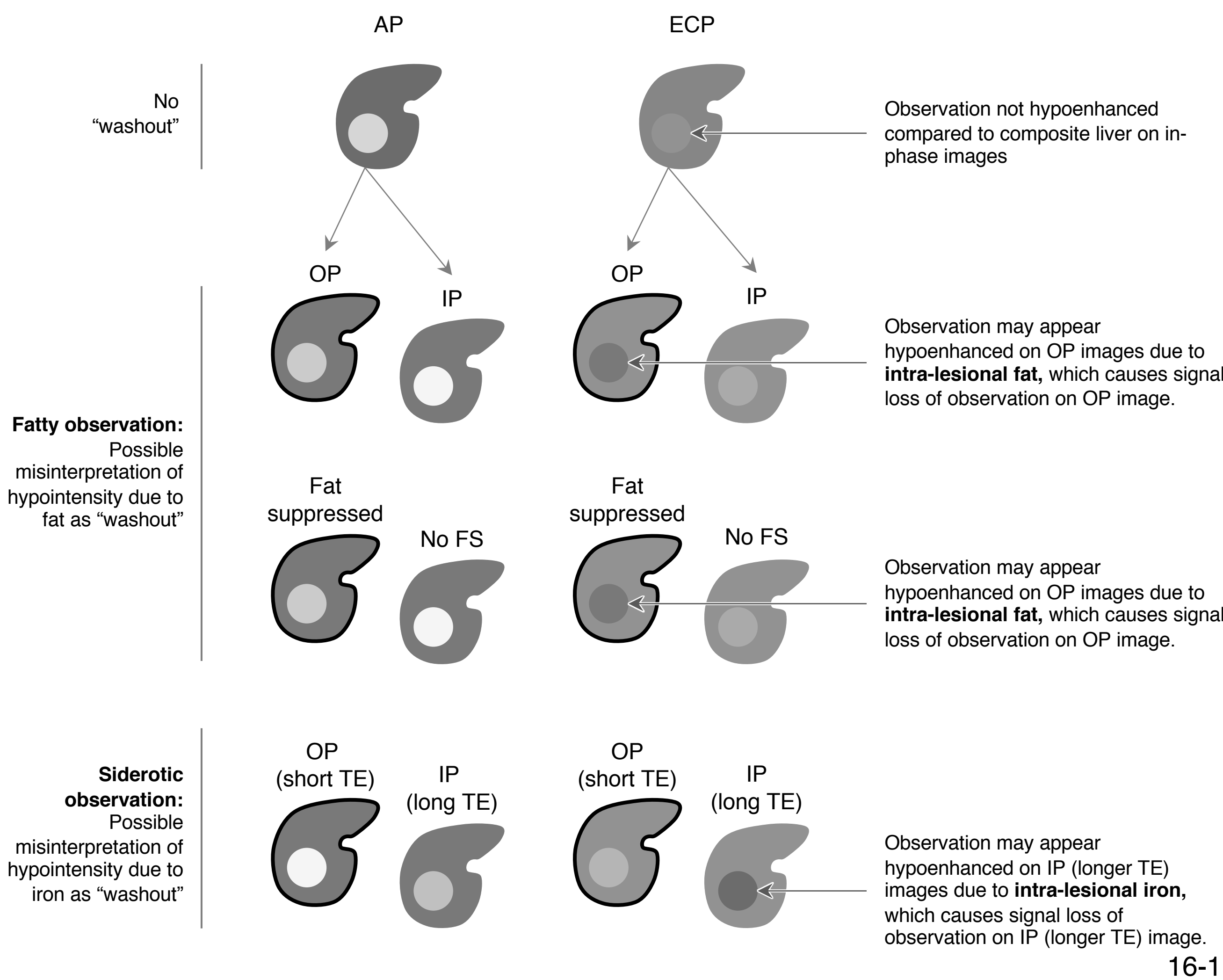
RADLEX ID: RID39486

Pitfalls & practical considerations (Cont'd)

Misinterpretation pitfalls

Observations with intrinsic hypointensity may be dark relative to liver in the postarterial ECP, which could be misinterpreted as “washout”.

- This misinterpretation is more common on MRI and may be due to the presence within the observation of
  - fat, which causes signal loss on out-of-phase or fat-suppressed images
  - iron, which causes signal loss of gradient recalled echo images with longer echo times (TEs)



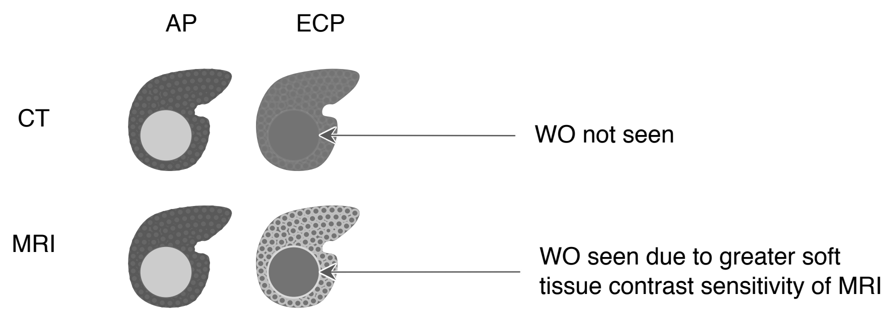
Washout Appearance ("Washout")

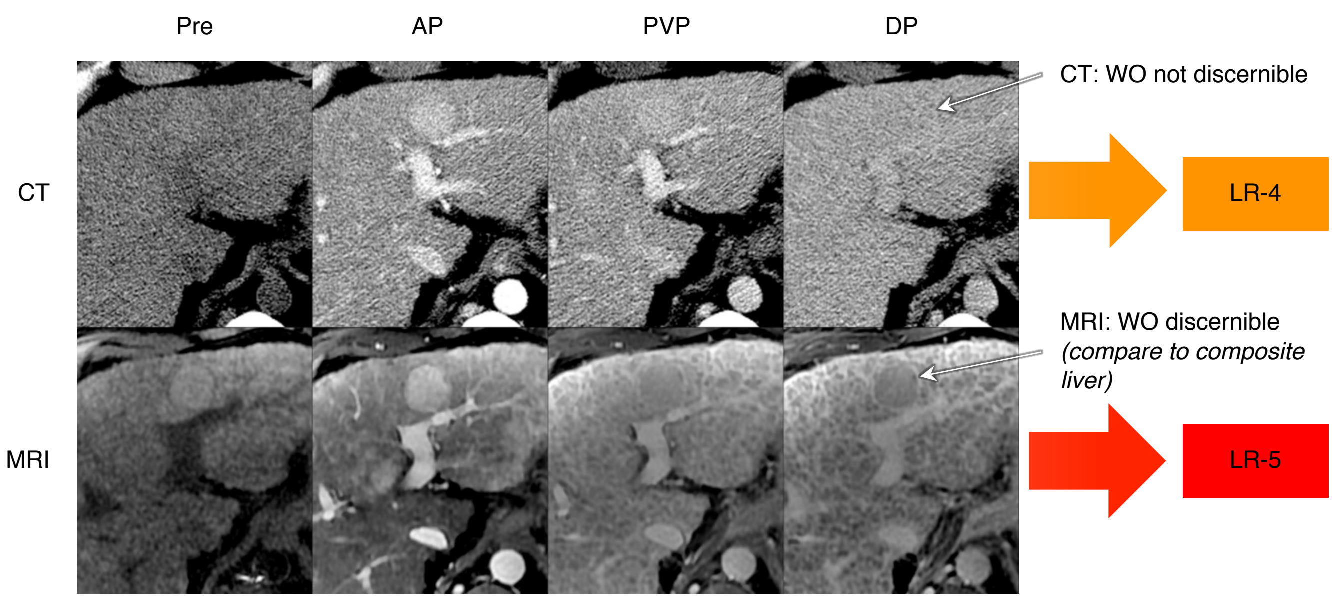
RADLEX ID: RID39486

Pitfalls & practical considerations (Cont'd)

Detection pitfalls

Technical factors/modality: Washout appearance may be more difficult to see on CT than MRI due to the greater soft tissue contrast sensitivity of MRI.





Tip: Consider MRI if CT is equivocal for "washout"

Washout Appearance (“Washout”)

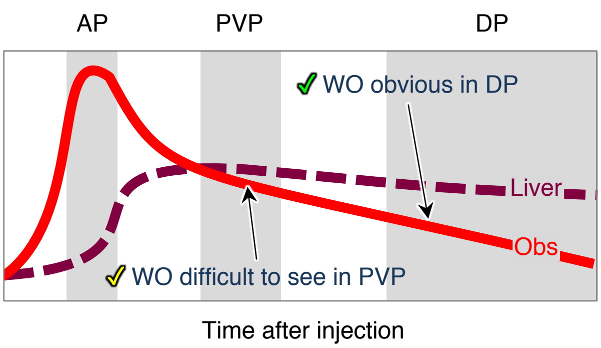
RADLEX ID: RID39486

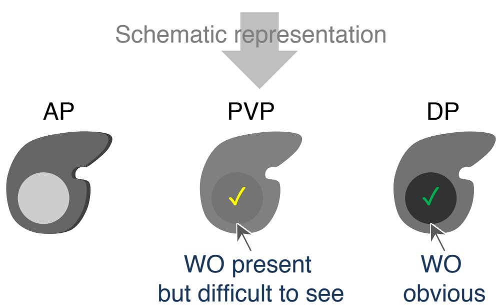
Pitfalls & practical considerations (Cont'd)

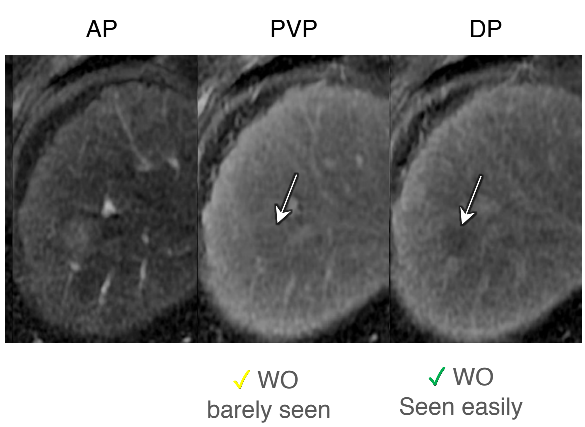
Detection pitfalls

Technical factors/phase: Washout appearance (WO) may be more difficult to detect in PVP than in DP. Some HCCs appear to wash out only in the DP.

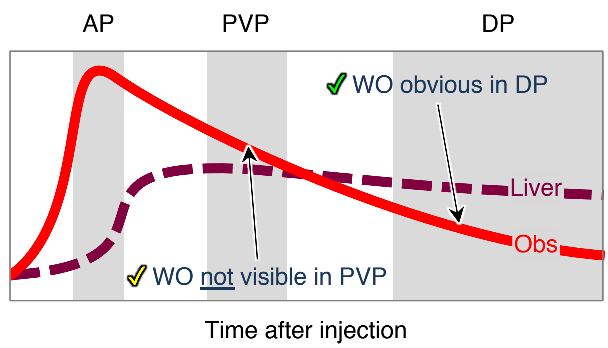
- WO more difficult to see in PVP than DP

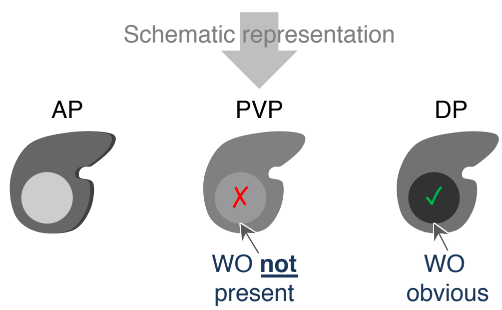


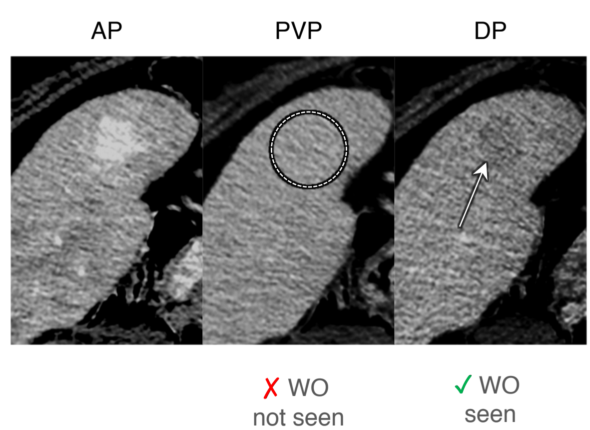




- WO visible only in the DP







Tip: LI-RADS recommends routine DP imaging, not just PVP, when using ECA or gadobenate *(see Chapter 12).*

Washout Appearance ("Washout")

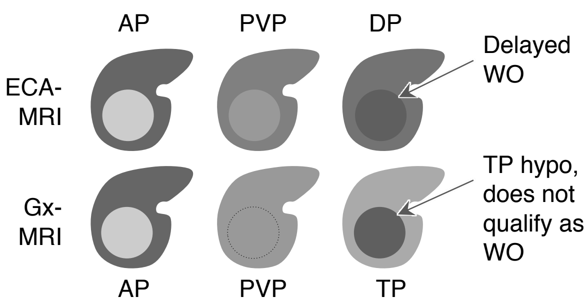
RADLEX ID: RID39486

Pitfalls & practical considerations (Cont'd)

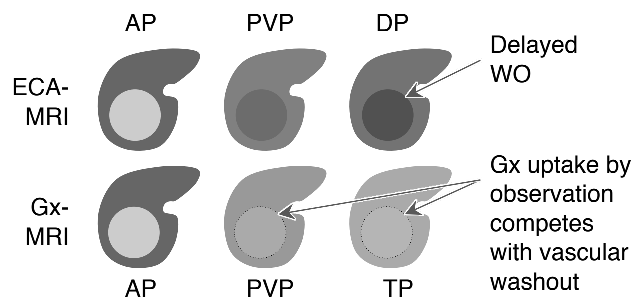
Detection pitfalls

Technical factors/contrast agent: Washout appearance may be more difficult to detect on gadoxetate-MRI than extracellular agent-MRI due to:

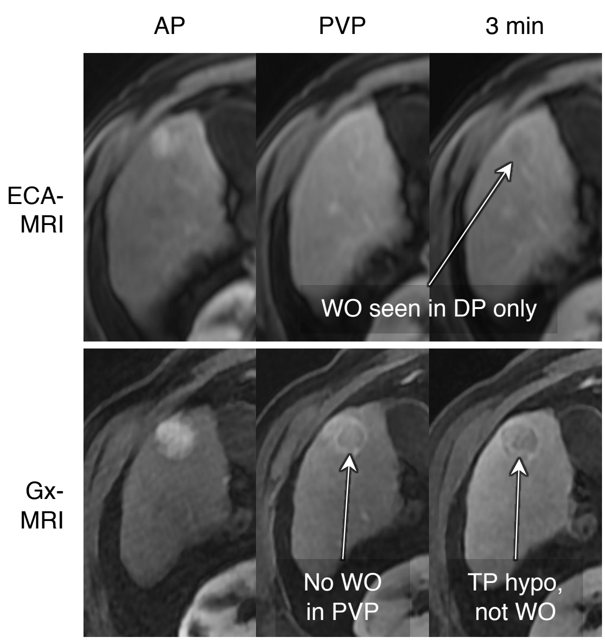
- stringent requirement that "washout" with gadoxetate must occur in or even before PVP



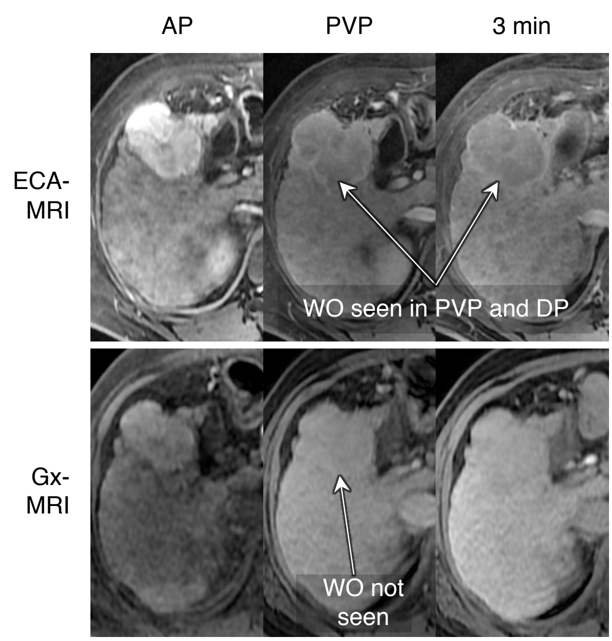
- hepatocellular uptake of Gx by observation matching liver, sometimes seen in PVP



WO in DP with ECA; no WO with Gx



WO in PVP & DP with ECA; no WO with Gx



Tip: Consider ECA-MRI if gadoxetate-MRI is equivocal for "washout"

Washout Appearance (“Washout”)

RADLEX ID: RID39486

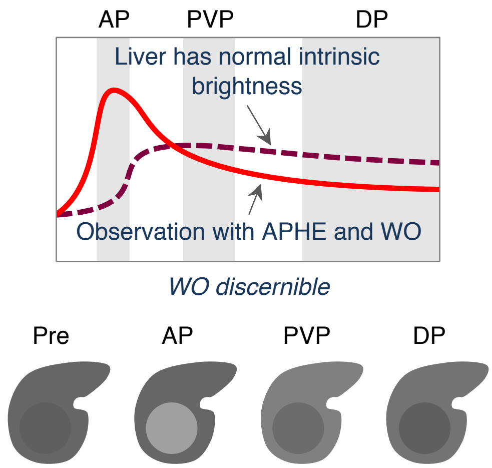
Pitfalls & practical considerations (Cont'd)

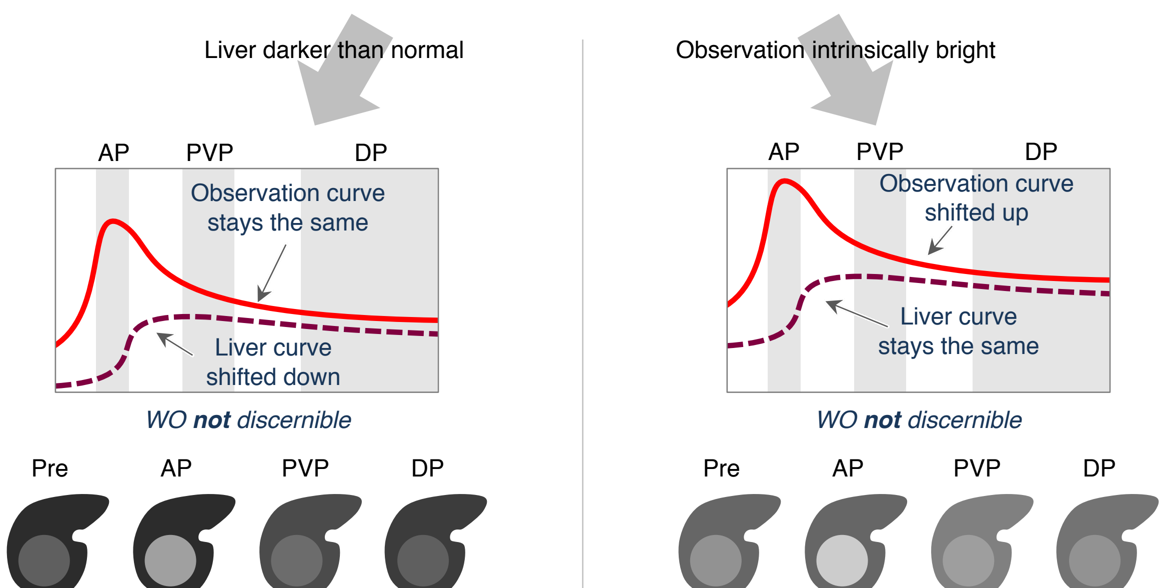
Detection pitfalls

Washout appearance may be difficult to detect if:

- Background liver is darker than normal
  - steatosis (CT or MRI)
  - iron overload (MRI)

- Observation is intrinsically bright
  - hyperattenuating (CT)
  - T1 hyperintense (MRI)





Tip: Consider subtraction to characterize “washout” in these situations. [Page 16-104]

Washout Appearance ("Washout")

RADLEX ID: RID39486

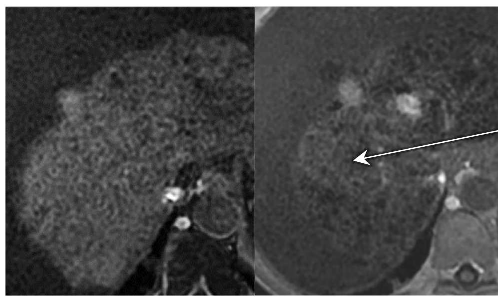
Pitfalls & practical considerations (Cont'd)

Detection pitfalls

Washout appearance may be difficult to detect if background liver is darker than normal

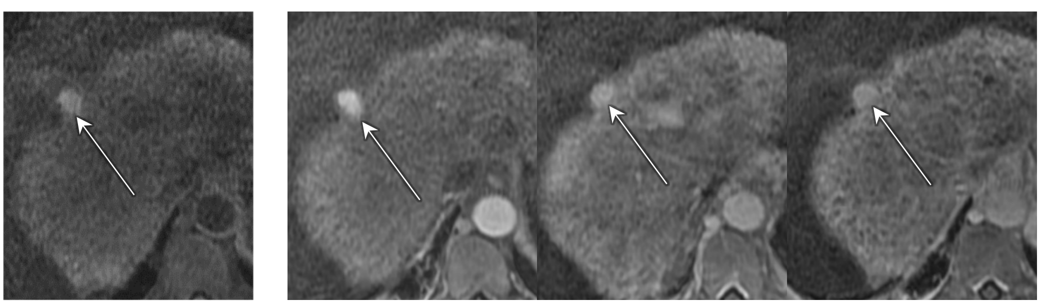
- Steatosis (CT or MRI)
- Iron overload (MRI)

OP TE 2.2 ms | IP TE 4.3 ms



Signal loss in liver on longer TE due to Fe overload ($T2^*$ shortening)

Pre | AP | PVP | DP



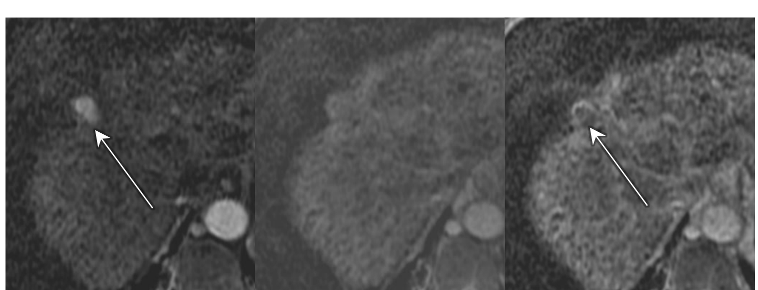
Parenchyma has low signal on Pre due to Fe → observation appears hyper relative to liver

Observation remains visually hyper to liver on AP, PVP and DP: no visible WO

Perform subtractions

AP - Pre | PVP - Pre | DP - Pre

Subtractions



Sub confirms APHE

Sub confirms DP WO

Washout Appearance ("Washout")

RADLEX ID: RID39486

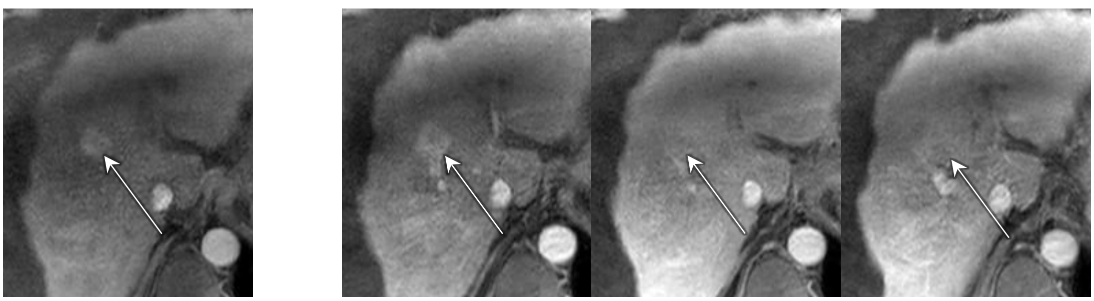
Pitfalls & practical considerations (Cont'd)

Detection pitfalls

Washout appearance may be difficult to detect if observation is intrinsically bright precontrast

- Hyperattenuating (CT)
- T1 hyperintense (MRI)

Pre | AP | PVP | DP



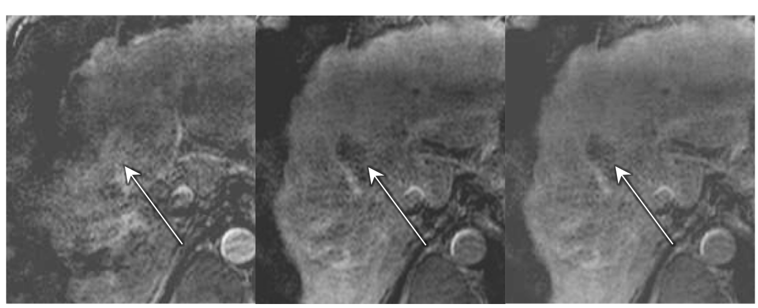
Observation is is intrinsically hyperintense relative to liver

Observation is visually hyperintense to liver on AP and is iso on PVP and DP: no visible WO

Perform subtractions

Subtractions

AP - Pre | PVP - Pre | DP - Pre



Sub confirms APHE

Subs confirm PVP WO and DP WO

Washout Appearance ("Washout")

RADLEX ID: RID39486

Pitfalls & practical considerations (Cont'd)

With MRI with any contrast agent:

May: With caution use subtractions to characterize "washout" at MRI if observation is intrinsically T1 hyperintense and has APHE. See *page 16-104*.

Do: Report if subtractions were used to asses "washout"

- State: "subtractions were used in determining the presence of washout appearance"

With extracellular agents and gadobenate:

The combination of PVP and DP is more sensitive than PVP alone for detecting "washout". Hence, LI-RADS recommends routine DP imaging, not just PVP, when using ECA or gadobenate. See *Chapter 12*.

With gadoxetate disodium:

Hypointensity in transitional or hepatobiliary phase does not qualify as "washout". See *page 16-96*.

Do: Compare observation to composite liver tissue (visual average of nodules and fibrosis) on postarterial extracellular phase images. See *page 16-103*.

Peripheral "Washout"

RADLEX ID: RID49817

Definition

Spatially defined subtype of "washout" in which apparent washout is most pronounced in periphery of observation.

Synonyms

Peripheral washout; venous/portal venous/delayed/late phase peripheral hypoenhancement, peripheral hypoattenuation, or hypointensity; peripheral deenhancement

Terminology

The term peripheral washout appearance or peripheral "washout" is preferred for the reasons mentioned earlier. See page 16-84.

Peripheral hypointensity in TP or HBP should not be termed peripheral "washout" but instead TP or HBP targetoid appearance. See page 16-227.

Applicable modalities

CT, MRI (all contrast agents)

Peripheral "washout" occurs only with small molecular weight contrast agents such as those used in CT and MRI; it does not occur with the blood pool agents used in CEUS. For CEUS, all washout is nonperipheral. See CEUS Manual (pending).

Type of feature

Targetoid LR-M feature

Peripheral “Washout”

RADLEX ID: RID49817

Effect on categorization

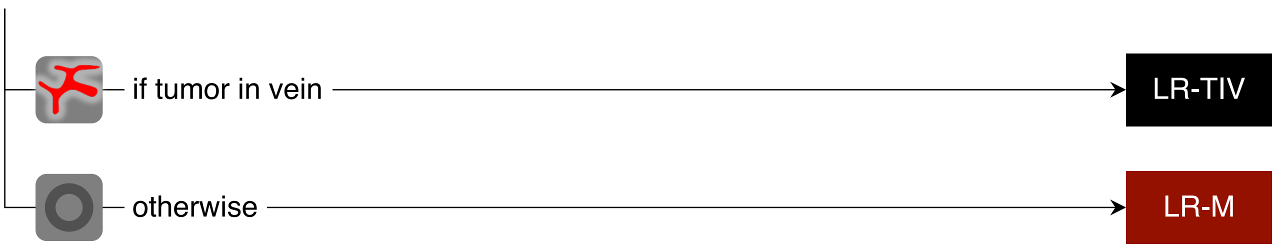
Peripheral “washout” is sufficient for LR-M. See *page 16-9*.

By itself, it is enough for LR-M categorization.

Thus, all untreated observations with peripheral “washout” are LR-M, regardless of other imaging features.

- Exceptions:
  - If there is tumor in vein, categorize as LR-TIV.
  - If observation is path proven, report path diagnosis, not LI-RADS category.

Nonpath-proven observation with peripheral “washout”



Peripheral “washout” is not required for LR-M. See *page 16-9*.

Observations without peripheral “washout” can be LR-M if other LR-M features are present.

- Example: Observation with rim APHE and delayed central enhancement but not peripheral “washout”

Peripheral “Washout”

RADLEX ID: RID49817

Biological basis

The peripheral area in a large (≥ 2 cm) mass-forming intrahepatic cholangiocarcinoma (iCCA) is hypercellular with compact tumor glands and small extracellular volume, leading to rapid “washout” of injected contrast material.

In contrast, the center of a large iCCA is composed mainly of loose connective tissue with abundant intercellular matrix and large extracellular volume, leading to delayed retention of small-molecular weight contrast material such as used for CT or MRI.

Thus, when using small-molecular weight contrast material, the apparent washout may be most pronounced in and potentially visible only in the periphery. The center, conversely, tends to show delayed enhancement.

(Peripheral “washout” does not occur with blood pool agents such as those used in CEUS. The bubbles/particles are too large to extravasate from the vascular space into the interstitium of the tumor center. Instead, the bubbles/particles wash out rapidly from the entire tumor – the center as well as the periphery. See CEUS Manual (Pending).

Peripheral “washout” is characteristic of iCCA and other non-HCC malignancies, but not of HCC, which tends to have “washout” unconfined to the tumor periphery. See *Chapter 5*.

Peripheral “washout” is a manifestation of targetoid appearance, a constellation of LR-M features with similar biological basis and often co-existing in the same observation. This constellation includes rim APHE, peripheral “washout”, delayed central enhancement, targetoid restriction, and targetoid appearance in TP and/or HBP images. See *page 16-205*.

Summary of evidence

Peripheral “washout” is commonly seen in large (≥ 2 cm) iCCAs. This feature has been shown to help differentiate large iCCA from large HCC. Differentiation of small iCCA from small HCC remains difficult.

Peripheral “washout” occurs in association with other targetoid LR-M features since it is thought to reflect the same underlying pathology: peripheral arterialization and hypercellularity in conjunction with central fibrosis and ischemia. The frequency and diagnostic accuracy of peripheral “washout” in the absence of other targetoid LR-M features is unknown.

Peripheral “Washout”

RADLEX ID: RID49817

Characterization

Characterize by comparing postarterial extracellular phase images:

- For ECA and gadobenate: PVP, DP, or both. DP images may be more sensitive for characterizing “washout” than PVP using these agents. See *page 16-119*.
- For gadoxetate: PVP only. “Washout” cannot be characterized on TP or HBA using this agent. See *page 16-96*.

See *page 16-90* for general concepts about “washout” and *page 16-104* for use of subtractions.

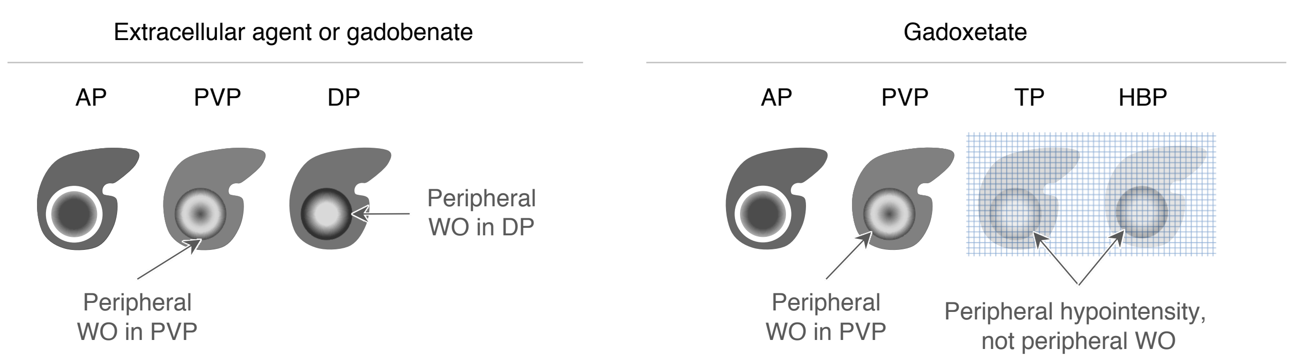
Peripheral washout appearance is present if **BOTH** of the following are met:

- The observation enhances to at least some degree: completely nonenhancing observations (e.g., cysts) cannot be characterized as having “washout”.

AND

- The observation periphery is darker than liver and darker than observation center in the postarterial extracellular phase source images or (postarterial extracellular phase – precontrast) subtraction images.

- Note that APHE is not required. Peripheral “washout” can occur even in absence of APHE so long as observation enhances to some degree.



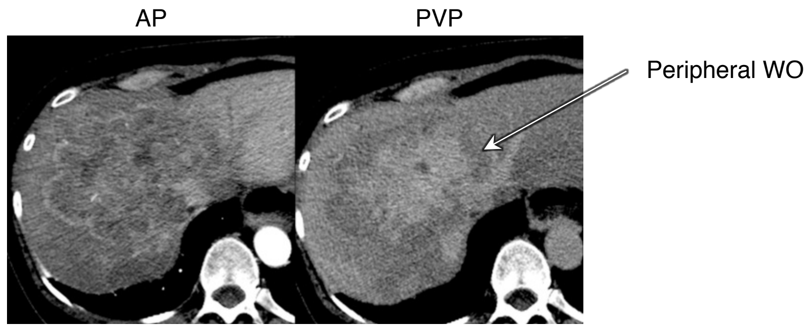
- Peripheral WO must be assessed in PVP
- Neither TP nor HBP can be used to assess peripheral WO

Peripheral "Washout"

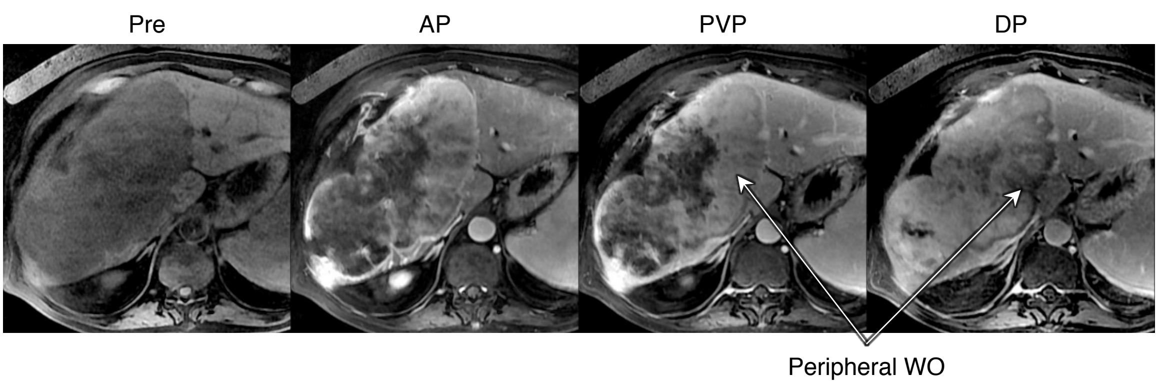
RADLEX ID: RID49817

Characterization (Cont'd)

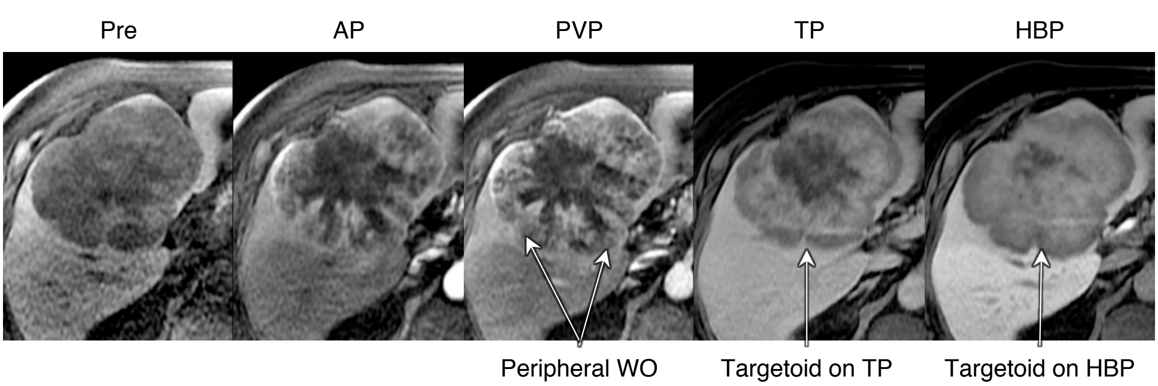
Example: CT



Example: ECA-MRI



Example: Gx-MRI



Peripheral "Washout"

RADLEX ID: RID49817

Characterization (Cont'd)

If unsure

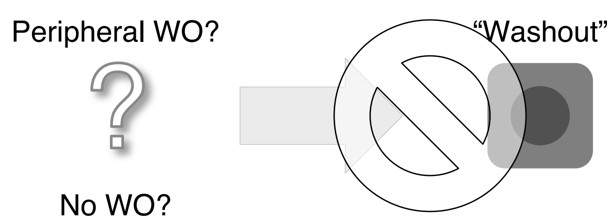
If unsure about peripheral WO vs no WO, characterize as no WO

- *Rationale: LI-RADS imaging features are characterized as present only if there is certainty*

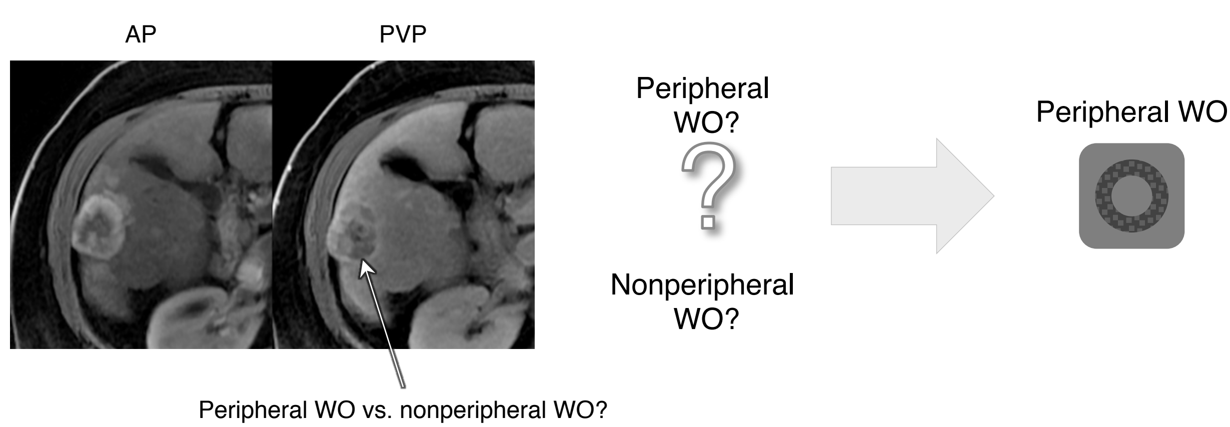
If unsure about peripheral WO vs nonperipheral WO, characterize as peripheral WO

- *Rationale: provides low threshold for alerting referrer to possibility of non-HCC malignancy*

Example: peripheral WO vs no WO, characterize as no WO



Example: peripheral WO vs nonperipheral WO, characterize as nonperipheral WO



Peripheral “Washout”

RADLEX ID: RID49817

Pitfalls & practical considerations

See page 16-108 for general “washout” pitfalls, which include optical illusion pitfalls, misinterpretation pitfalls, and detection pitfalls.

Some lesions may appear to wash out more in their center than in their periphery in the postarterial ECP. While this pattern (central “washout” and peripheral delayed enhancement) arguably could be described as “targetoid”, it is not peripheral “washout” and it is not a feature of LR-M.

Abscesses have a concentric structure and may manifest rim APHE and/or targetoid diffusion restriction. However, abscesses do not show peripheral “washout” since the rim of the abscess cavity is composed of fibrous or granulation tissue that progressively enhances. Thus, unlike some targetoid features (rim APHE, targetoid restriction), peripheral “washout” excludes abscess from consideration.

The distinction between peripheral and nonperipheral washout is not always straightforward. If unsure, characterize as peripheral washout. See page 16-130.

Small iCCA (< 3 cm) may not have peripheral “washout”, instead having nonperipheral “washout”, complicating their differentiation from HCC. Discussed on page 16-132.

Some HCCs may have peripheral “washout”. Discussed on page 16-133.

Peripheral “washout” should be differentiated from a nonenhancing capsule. Discussed on page 16-134.

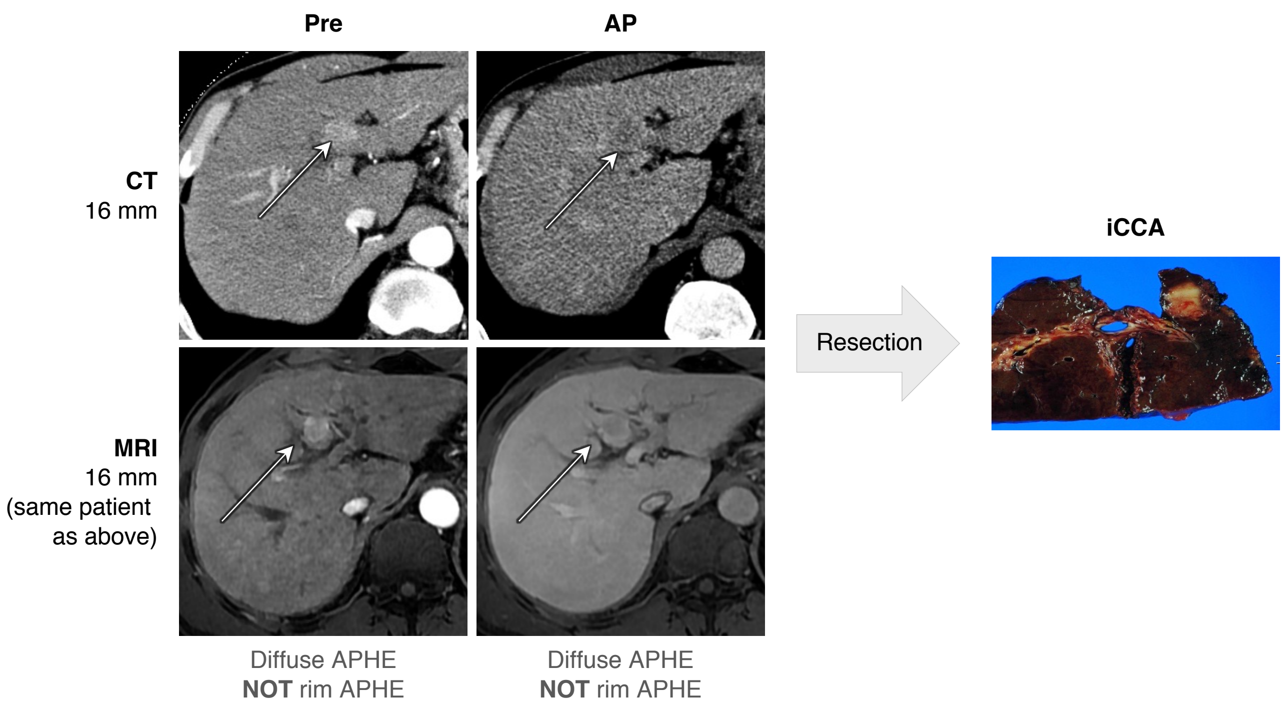
Peripheral “Washout”

RADLEX ID: RID49817

Pitfalls & practical considerations

Small iCCA (< 3 cm) may not have peripheral WO, instead having nonperipheral WO, complicating their differentiation from HCC.

Example: path-proven iCCA with nonrim APHE and nonperipheral WO, 61-yo man with chronic HBV



⚠ Small iCCAs may be indistinguishable from HCCs in postarterial ECP, with both types of malignant neoplasms having nonperipheral WO

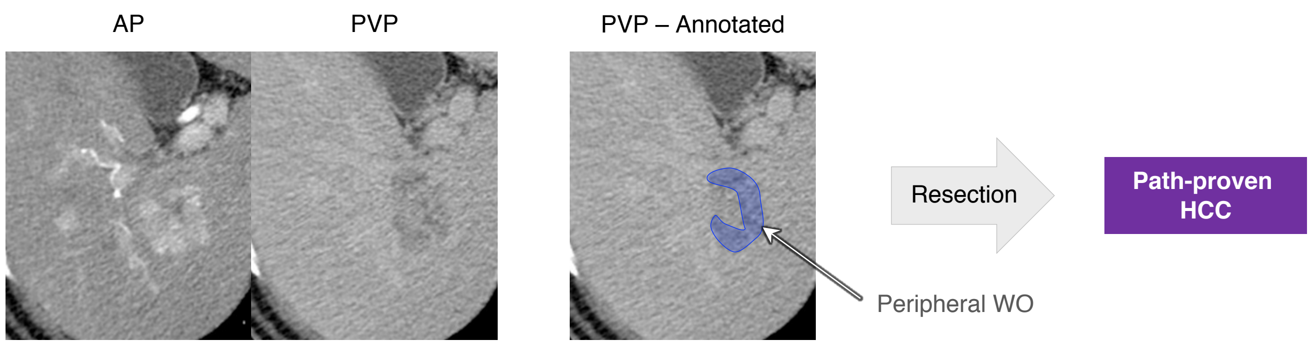
Peripheral “Washout”

RADLEX ID: RID49817

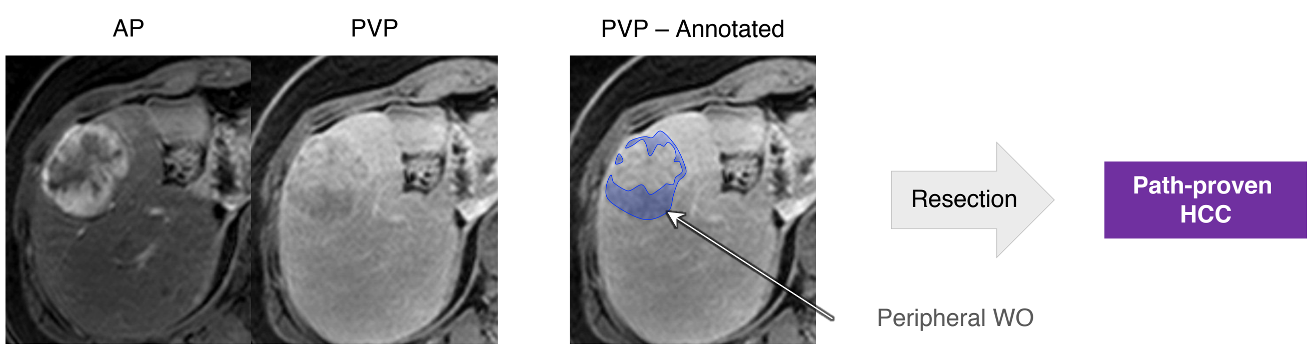
Pitfalls & practical considerations (Cont'd)

Some HCCs may have peripheral WO

Example (CT): HCC with peripheral WO



Example (MRI): Scirrhous HCC with peripheral WO



Peripheral "Washout"

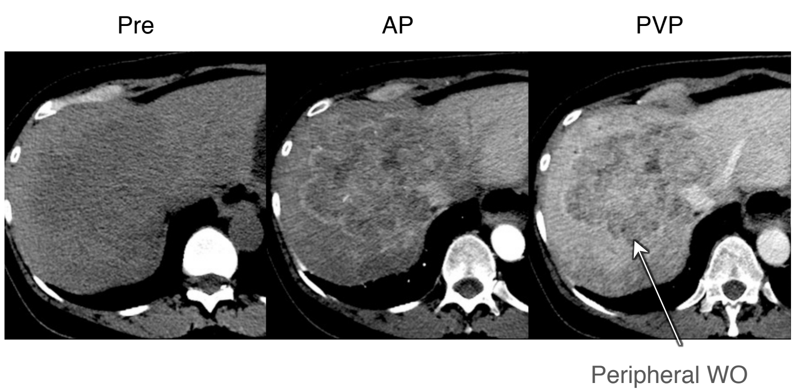
RADLEX ID: RID49817

Pitfalls & practical considerations (Cont'd)

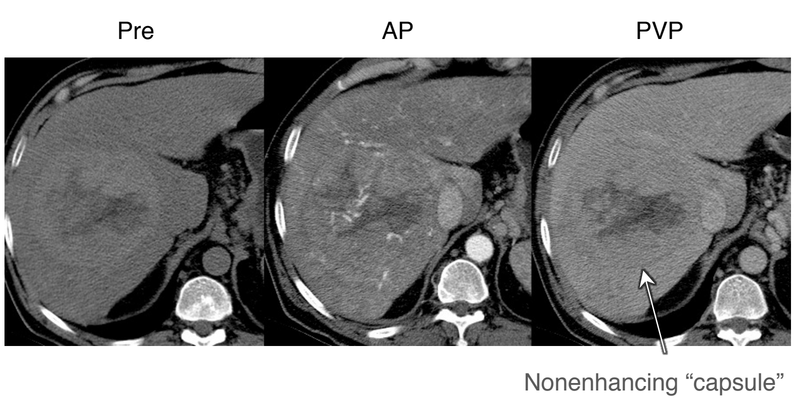
Peripheral "washout" should be differentiated from a nonenhancing capsule:

- Peripheral "washout" is assessed in the extracellular phase
- Nonenhancing "capsule" is usually assessed on noncontrast images or hepatobiliary phase after gadoxetate administration. Rarely, a nonenhancing "capsule" is visible in the extracellular phase as a dark (i.e., nonenhancing) rim.

Peripheral "washout" with ECA



Nonenhancing "capsule" with ECA



Peripheral "Washout"

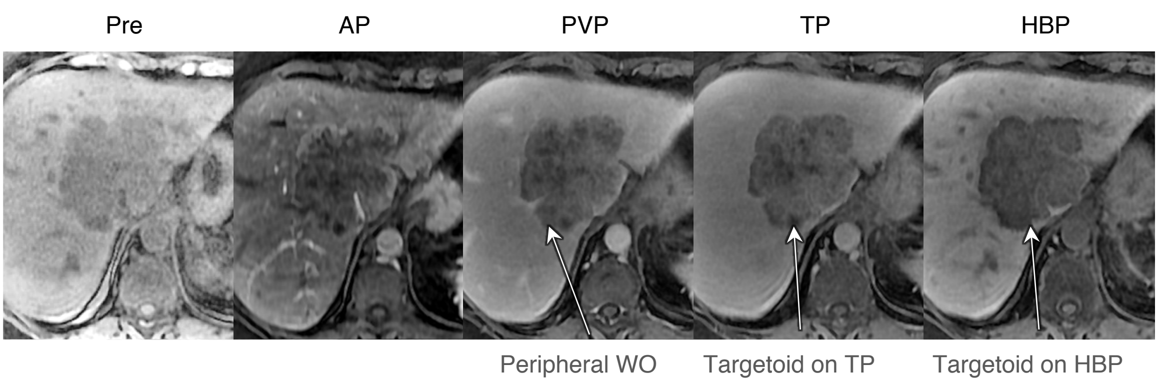
RADLEX ID: RID49817

Pitfalls & practical considerations (Cont'd)

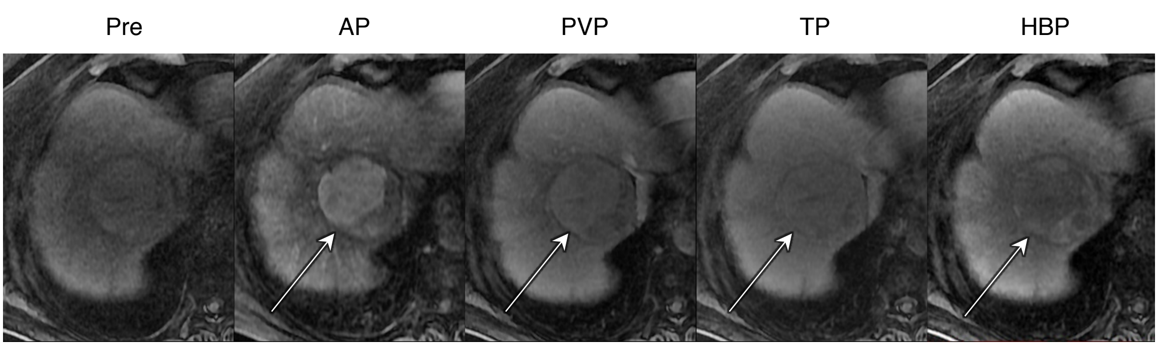
Peripheral "washout" should be differentiated from a nonenhancing capsule (cont'd):

- Peripheral "washout" is assessed in the extracellular phase
- Nonenhancing "capsule" is usually assessed on noncontrast images or hepatobiliary phase after gadoxetate administration. Rarely, a nonenhancing "capsule" is visible in the extracellular phase as a dark (i.e., nonenhancing) rim.

Peripheral "washout" with gadoxetate disodium



Nonenhancing "capsule" with with gadoxetate disodium



"Capsule" is hypointense to liver on all phases. This called nonenhancing "caspule"

Peripheral “Washout”

RADLEX ID: RID49817

Pitfalls & practical considerations (Cont’d)

Using extracellular agents or gadobenate:

Do: Characterize hyper (AP) → peripheral hypo (PVP) and/or hypo (DP) as peripheral “washout”

Do: Characterize iso (AP) → peripheral hypo (PVP) and/or peripheral hypo (DP) as peripheral “washout”

Using gadoxetate:

Do: Characterize hyper (AP) → peripheral hypo (PVP) as peripheral “washout”

Do: Characterize iso (AP) → peripheral hypo (PVP) as peripheral “washout”

Do not: Characterize hyper (AP) → iso (PVP) → peripheral hypo (TP or HBP) as peripheral “washout”. This is TP or HBP targetoid appearance.

Do not: Characterize iso (AP) → iso (PVP) → peripheral hypo (TP or HBP) as peripheral “washout”. This is TP or HBP targetoid appearance.

⚠ Peripheral hypointensity in transitional or hepatobiliary phase does not qualify as peripheral “washout”. This is considered TP or HBP targetoid appearance.

Peripheral "Washout"

RADLEX ID: RID49817

References

Chong YS, Kim YK, Lee MW, et al. Differentiating mass-forming intrahepatic cholangiocarcinoma from atypical hepatocellular carcinoma using gadoxetic acid-enhanced MRI. Clin Radiol. 2012;67(8):766-73.

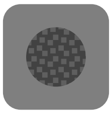
Iavarone M, Piscaglia F, Vavassori S, Galassi M, Sangiovanni A, Venerandi L, Forzenigo LV, Golfieri R, Bolondi L, Colombo M. Contrast enhanced CT-scan to diagnose intrahepatic cholangiocarcinoma in patients with cirrhosis. J Hepatol. 2013 Jun;58(6):1188-93.

Jeong HT, Kim MJ, Chung YE, Choi JY, Park YN, Kim KW. Gadoxetatedisodium-enhanced MRI of mass-forming intrahepatic cholangiocarcinomas: imaging-histologic correlation. AJR. 2013 Oct;201(4):W603-11.

Kang Y, Lee JM, Kim SH, Han JK, Choi BI. Intrahepatic mass-forming cholangiocarcinoma: enhancement patterns on gadoxetic acid-enhanced MR images. Radiology. 2012;264(3):751-60.

Kim SH, Lee CH, Kim BH, Kim WB, Yeom SK, Kim KA, Park CM. Typical and atypical imaging findings of intrahepatic cholangiocarcinoma using gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid-enhanced magnetic resonance imaging. J Comput Assist Tomogr. 2012 Nov-Dec;36(6):704-9.

Kim SJ, Lee JM, Han JK, Kim KH, Lee JY, Choi BI. Peripheral mass-forming cholangiocarcinoma in cirrhotic liver. AJR. 2007 Dec;189(6):1428-34.



Nonperipheral “Washout”

RADLEX ID: N/A

Definition

Spatially defined subtype of “washout” in which apparent washout is **not** most pronounced in the periphery of the observation. The “washout” may have a range of appearances such as diffuse and homogeneous, diffuse and heterogeneous, focal, scattered (patchy, spotty), nodule-in-nodule, or mosaic.

Synonyms

Washout; venous/portal venous/delayed/late phase hypoenhancement, hypoattenuation, or hypointensity; deenhancement

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Terminology

The term nonperipheral washout appearance or nonperipheral “washout”’ is preferred for the reasons mentioned earlier. See *page 16-84*.

For CEUS, all washout is nonperipheral. See CEUS Manual (pending).

Additionally, the term nonperipheral “washout” is clear, unambiguous, and the logical counterpart to the other spatial subtype (peripheral “washout”).

The term nonperipheral “washout” is used only rarely in the radiology literature, however. For simplicity and to keep jargon to a minimum, the general term “washout” may be used instead of the more specific term nonperipheral “washout” if its usage in this way is unambiguous.

Applicable modalities

CT, MRI (all contrast agents), CEUS

Type of feature

Major feature for HCC, but is neither required nor sufficient for LR-5. See *page 16-139*.

For discussion of washout on CEUS, See CEUS Manual (pending).

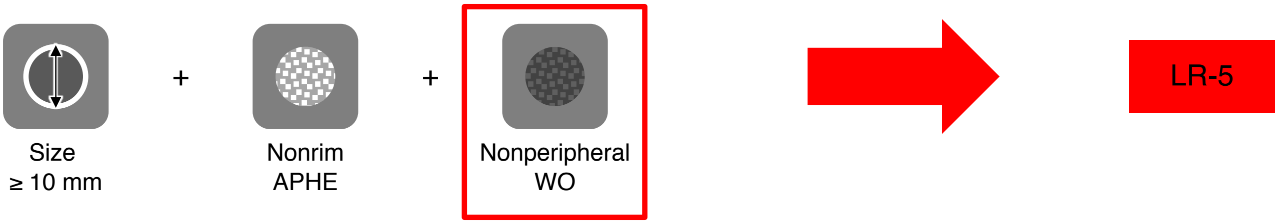
Nonperipheral "Washout"

RADLEX ID: N/A

Effect on categorization

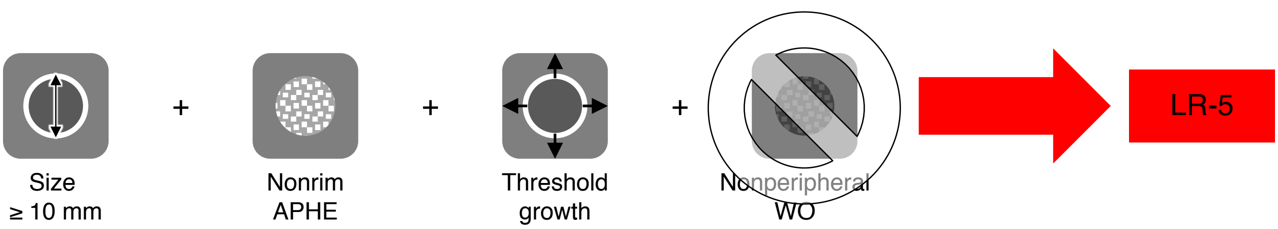
Nonperipheral "washout" is a major feature of HCC

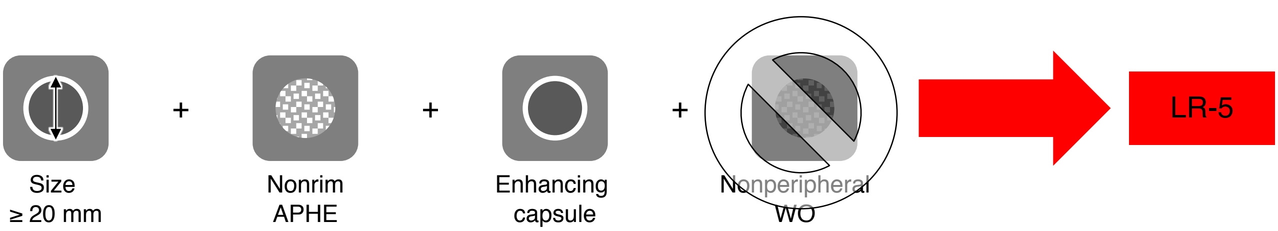
In combination with two other major features (nonrim APHE, size ≥ 10 mm), observations with nonperipheral "washout" can (and usually should) be categorized LR-5. However, nonperipheral "washout" is neither required nor sufficient for LR-5:



Nonperipheral "washout" is not required for LR-5.

Observations without nonperipheral "washout" *can* be LR-5. For example, the following observations are categorized LR-5 despite lacking "washout":





Nonperipheral “Washout”

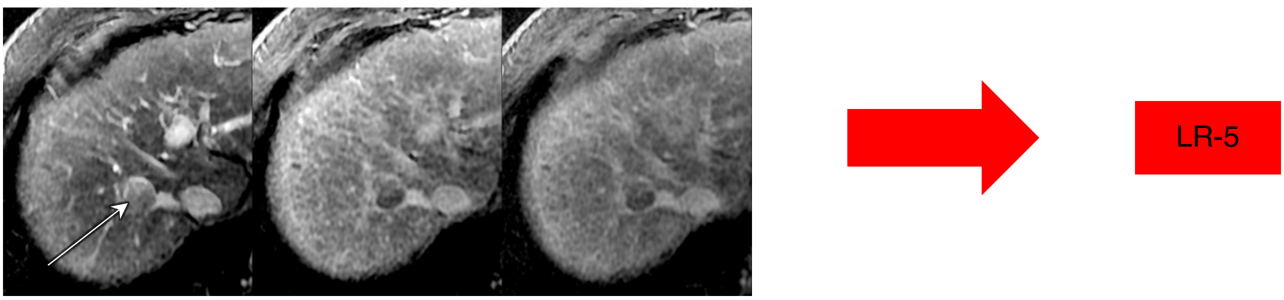
RADLEX ID: N/A

Effect on categorization

Nonperipheral “washout” is a major feature of HCC

In combination with two other major features (nonrim APHE, size ≥ 10 mm), observations with nonperipheral “washout” can (and usually should) be categorized LR-5. However, nonperipheral “washout” is neither required nor sufficient for LR-5.

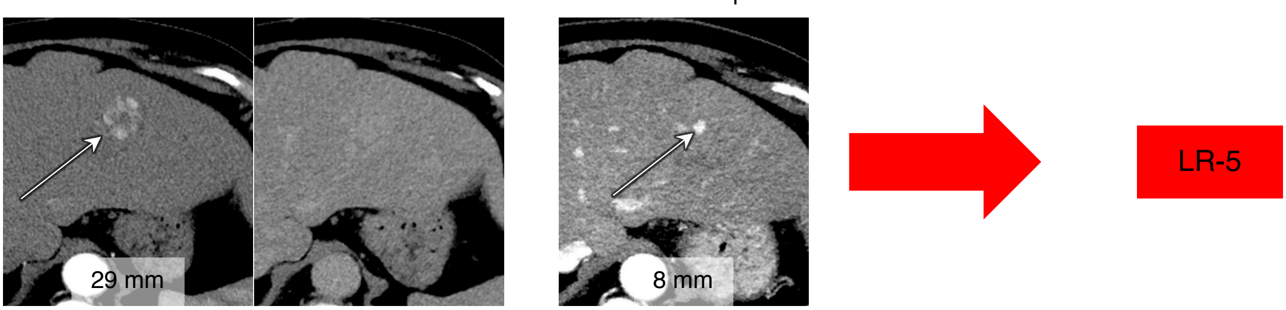
AP PVP DP



Nonperipheral “washout” is not required for LR-5.

Observations without nonperipheral “washout” *can* be LR-5. For example, the following observations are categorized LR-5 despite lacking ”washout”

AP PVP AP 3 months prior



✓TG, ✗ “washout”

AP PVP DP

✓Enhancing ”capsule”, ✗ “washout”

Nonperipheral "Washout"

RADLEX ID: N/A

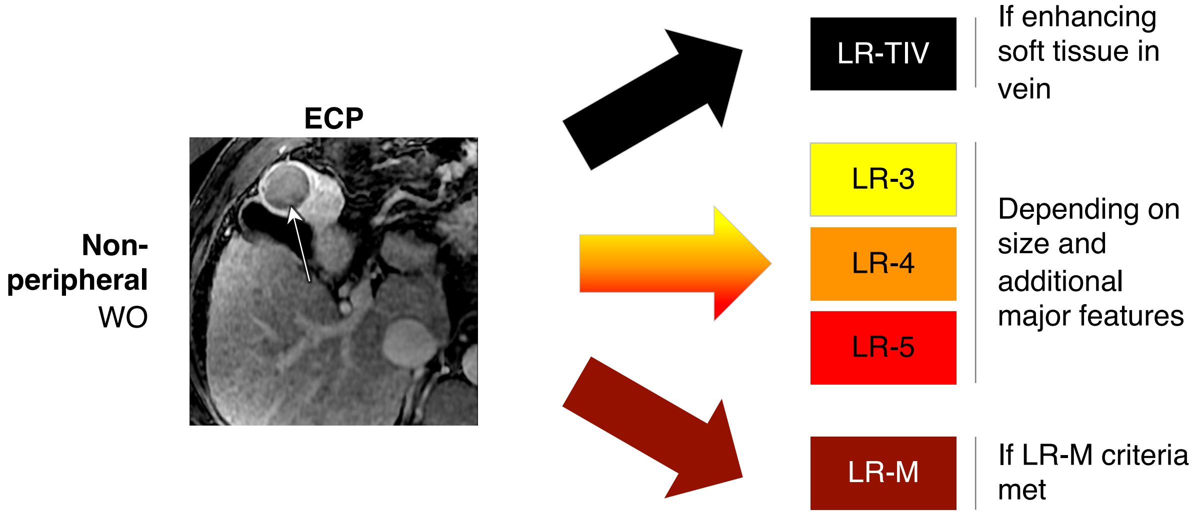
Effect on categorization (Cont'd)

Nonperipheral "washout" is not sufficient for LR-5.

Observations with nonperipheral "washout" *can* be other than LR-5.

For example, observations with nonperipheral "washout"

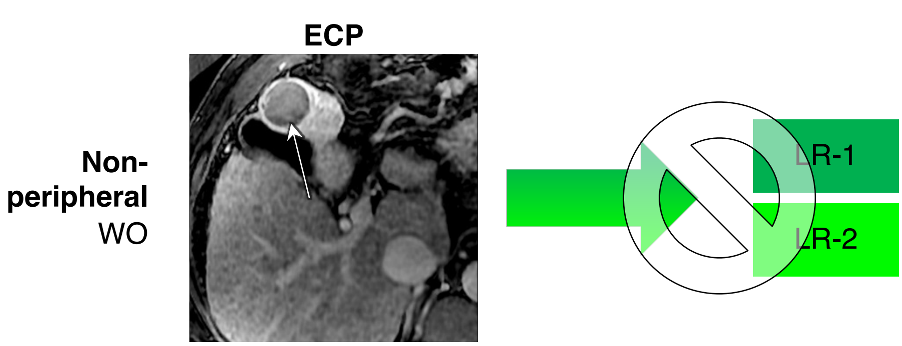
- LR-TIV (if enhancing soft tissue in vein)
- LR-3, LR-4, LR-5 (depending on size and additional major features)
- LR-M (if LR-M criteria met)



Nonperipheral "washout" excludes LR-1 and LR-2.

The presence of "washout" excludes LR-1 or LR-2 categorization from consideration.

- One exception: rarely, an LR-3 observation with "washout" can be downgraded to LR-2 by ancillary features favoring benignity such as ≥ 2-year stability or spontaneous size reduction.



Nonperipheral "Washout"

RADLEX ID: N/A

Effect on categorization (Cont'd)

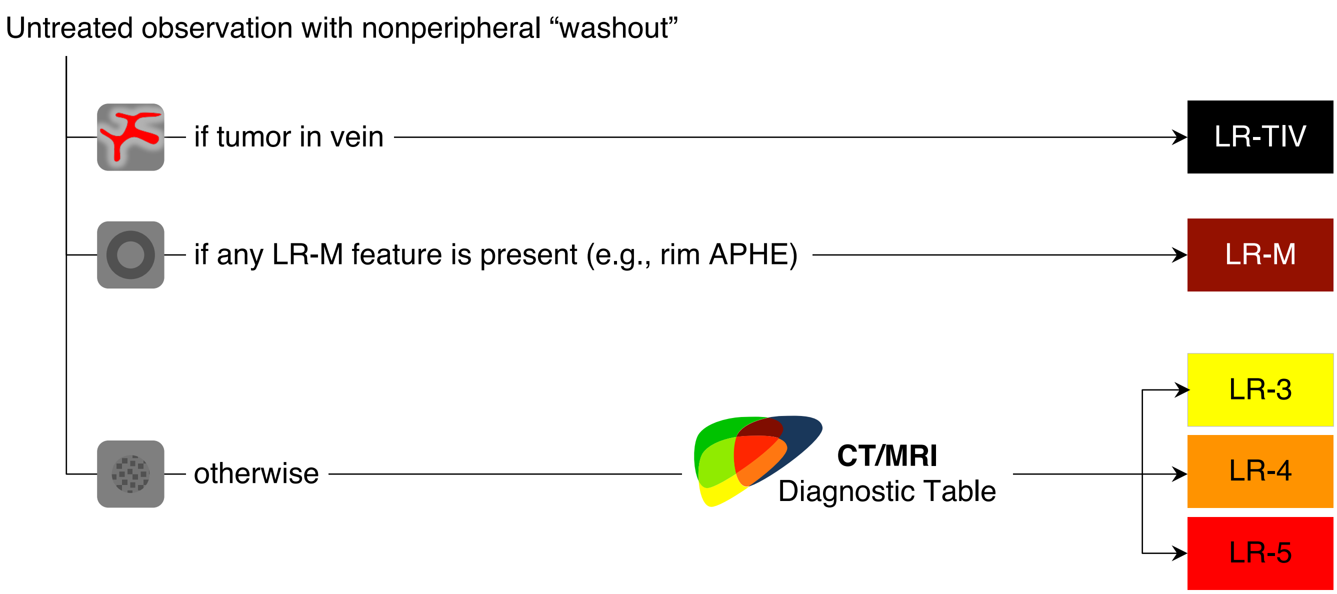
Observations with nonperipheral "washout" usually are categorized

- LR-M if there are other LR-M features
- LR-3, LR-4, or LR-5 otherwise.

Exceptions

- If there is tumor in vein, categorize as LR-TIV.
- If observation is path proven, report path diagnosis, not LI-RADS category.

See *CT/MRI Diagnostic Table*



Nonperipheral "Washout"

RADLEX ID: N/A

Biological basis

The biological basis of washout appearance is not well understood.

Multiple overlapping factors are presumed to contribute to true washout, including the following:

- Early venous drainage from observation
- Reduced portal venous blood supply to observation relative to portal venous supply to liver
- Hypercellularity of observation (i.e., reduced extracellular space)

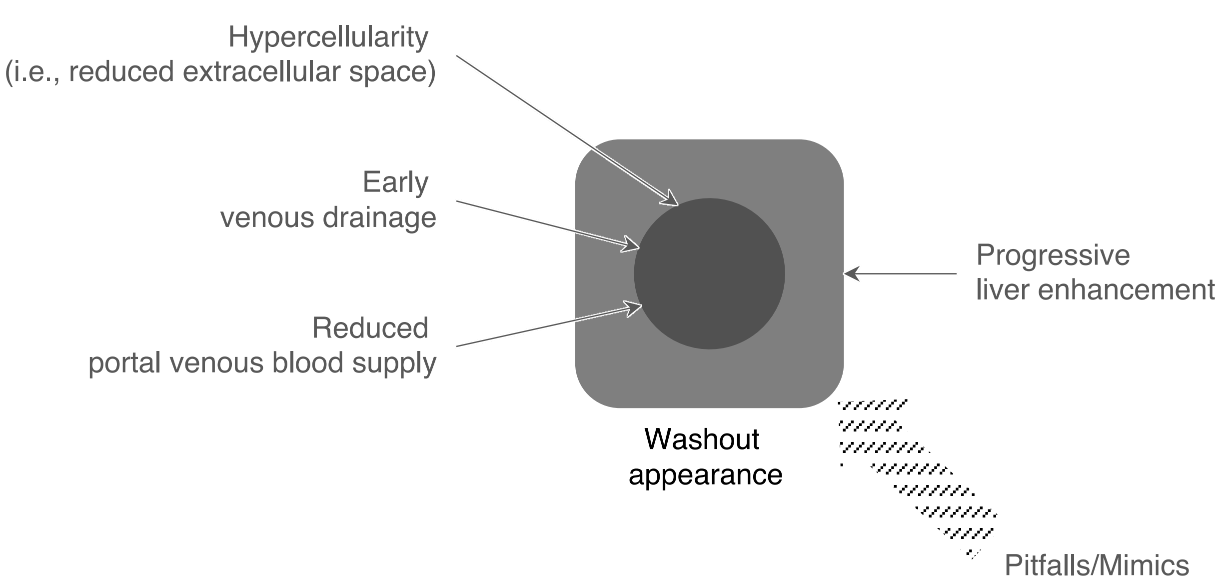
Progressive enhancement of background liver due to increased extracellular space (e.g., abundant fibrosis) also may contribute to the appearance of washout although this does not reflect true washout.

Additionally, there are important pitfalls that can mimic true washout:

- Hypoattenuation/hypointensity of observation relative to liver:
  - Lesions with high fat content (CT, MRI out of phase, MRI with fat suppression)
  - Lesions with high iron content (MRI)
  - So-called hypovascular lesions that hypoenhance relative to liver on all phases
- Illusion of "washout" due to presence of enhancing "capsule" or surrounding enhancing confluent fibrosis

Thus, the visually assessed temporal reduction in enhancement relative to liver may be caused by factors other than true washout.

Factors presumed to contribute to washout appearance



Nonperipheral "Washout"

RADLEX ID: N/A

Summary of evidence

When used as a stand-alone criterion, "washout" has wide ranging specificity (62-100%); however, when used in combination with APHE, "washout" has very high specificity (95-100%) in studies published since 2005.

For these reasons, "washout" is a major criterion of HCC in most imaging algorithms.

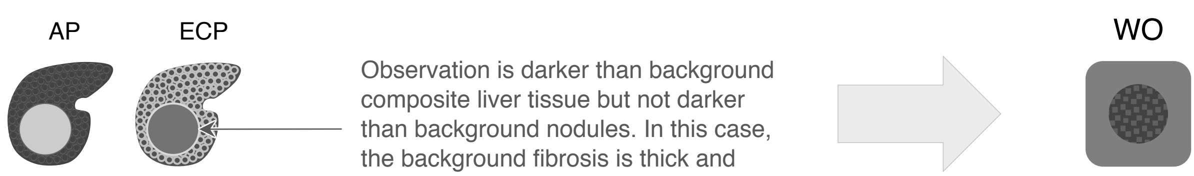
In the 2018 version of LI-RADS, "washout" is a higher ranked major feature than "capsule".

Hence,

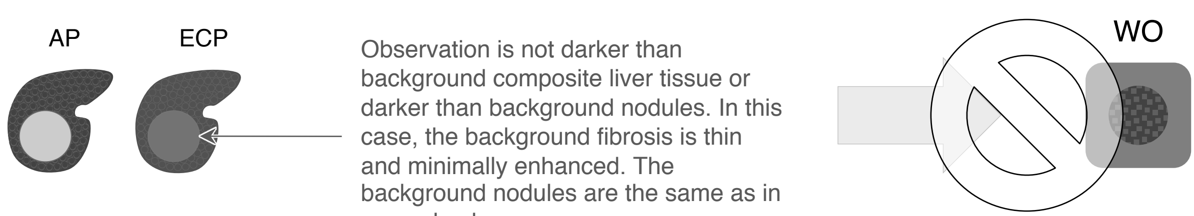
- the combination of APHE and "washout" permits LR-5 categorization for observations as small as 10 mm, even if other additional major features are absent BUT
- the combination of APHE and "capsule" requires observations to be at least 20 mm, unless other additional major features are present.

The rationale for making "washout" a higher ranked major feature than "capsule" is that "washout" has been validated more extensively and it provides greater inter-reader reliability. Additionally, this maintains harmony with the AASLD guidelines, which ranks "washout" more highly.

Comment: Although there is scientific evidence supporting "washout" as a major feature of HCC, there is little evidence to inform its exact definition, as the literature has been unclear on this issue. Thus, the LI-RADS definition of "washout" was developed mainly on expert opinion and the inferred meaning from published papers. In particular, in the current LI-RADS definition, "washout" should be assessed by comparing observations to composite liver tissue, i.e., a visual average of background nodules and fibrosis. Based on this definition, the following would qualify as "washout"



… but the following would not:



Research is needed to validate the LI-RADS definition or inform its refinement.

Nonperipheral "Washout"

RADLEX ID: N/A

Characterization

Characterize by comparing postarterial extracellular phase images:

- For ECA and gadobenate: PVP, DP, or both. DP images may be more sensitive for characterizing "washout" than PVP using these agents. See page 16-118.
- For gadoxetate: PVP only. "Washout" cannot be characterized on TP or HBA using this agent. See page 16-96.

See page 16-90 for general concepts about "washout" and page 16-104 for use of subtractions.

Nonperipheral washout appearance is present if **BOTH** of the following are met:

- The observation enhances to at least some degree: completely nonenhancing observations (e.g., cysts) cannot be characterized as having "washout".
  - Note that APHE is not required. "Washout" can occur even in absence of APHE so long as observation enhances to some degree.

  AND

- At least part of the observation is darker than liver in the postarterial extracellular phase source images or (postarterial extracellular phase – precontrast) subtraction images

  AND

- The dark part is not confined to the periphery

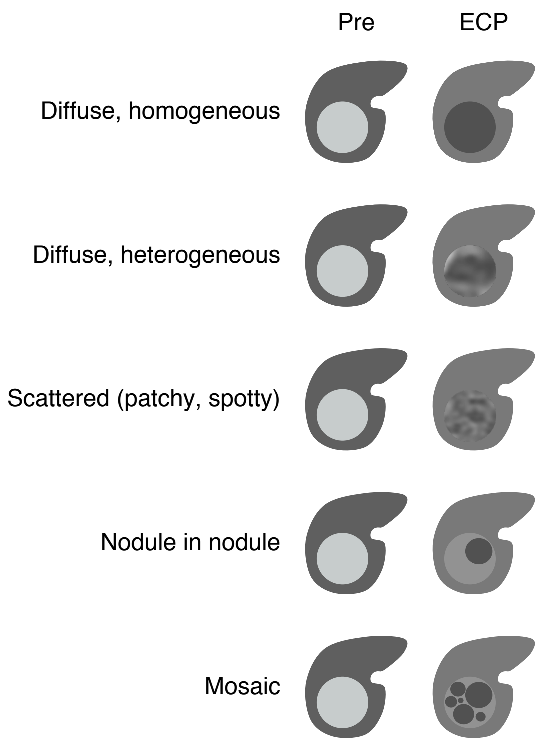
- Note that APHE is not required. Peripheral "washout" can occur even in absence of APHE so long as observation enhances to some degree.

Nonperipheral “Washout”

RADLEX ID: N/A

Characterization (Cont’d)

Nonperipheral “washout” can be diffuse and homogeneous, diffuse and heterogeneous, scattered (patchy, spotty), nodule-in-nodule, mosaic.



Any of these spatial patterns qualifies as “washout” so long as the “washout” is unequivocal.

There is no minimum size for application of “washout”, rather its presence should be unequivocal in judgment of radiologist.

These patterns have variable specificity for HCC. See *next page (page 16-147)*.

Nonperipheral “Washout”

RADLEX ID: N/A

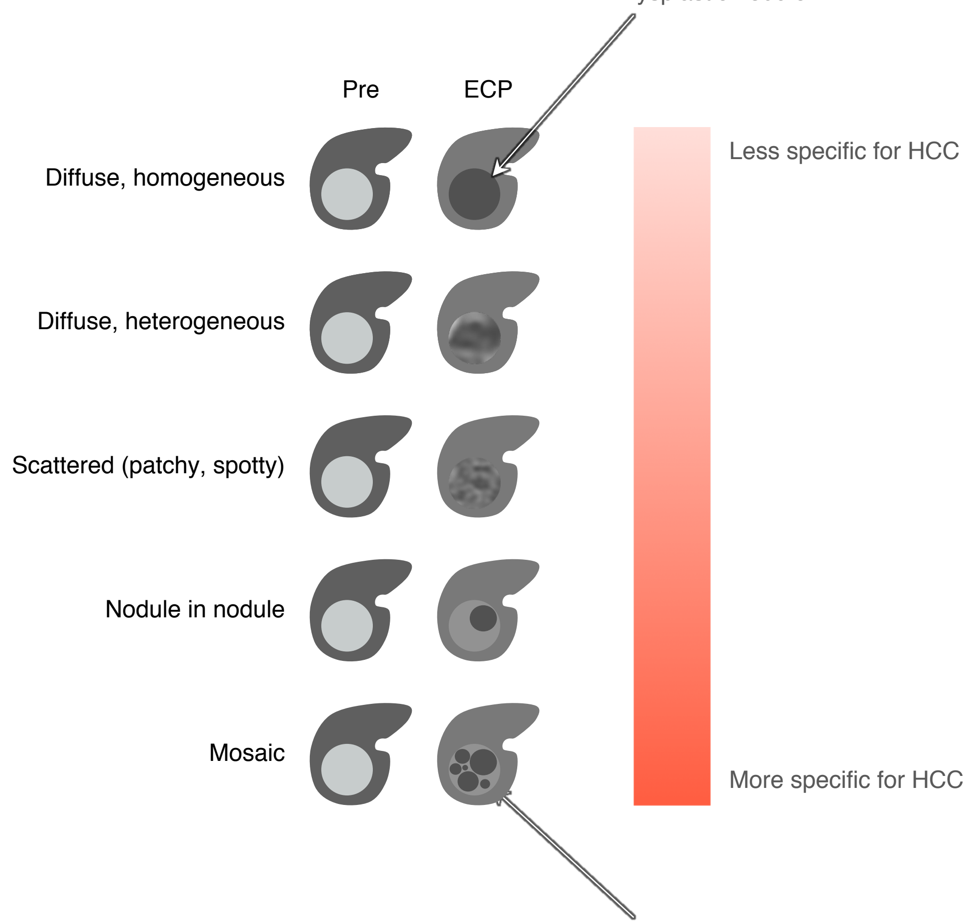
Characterization (Cont'd)

Five patterns of nonperipheral “washout” have variable specificity for HCC

Below they are listed in order of specificity from least specific (top) to most specific (bottom)

Differential diagnosis in high-risk patients of diffuse homogeneous “washout”

- Small HCC
- Small iCCA
- Small combined HCC-cholangiocarcinoma
- Small other non-HCC malignancies
- Dysplastic nodule



Differential diagnosis in high-risk patients of mosaic “washout”

- Progressed HCC
- Atypical:
  - iCCA
  - Combined HCC-cholangiocarcinoma
  - Other non-HCC malignancies

Nonperipheral “Washout”

RADLEX ID: N/A

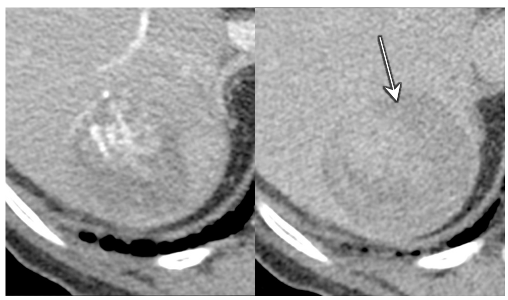
Characterization (Cont'd)

Examples: CT

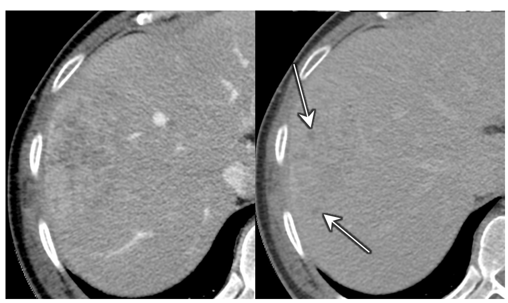
AP | ECP

Nonperipheral “washout”:
Diffuse, homogeneous

Nonperipheral “washout”:
Diffuse, heterogeneous

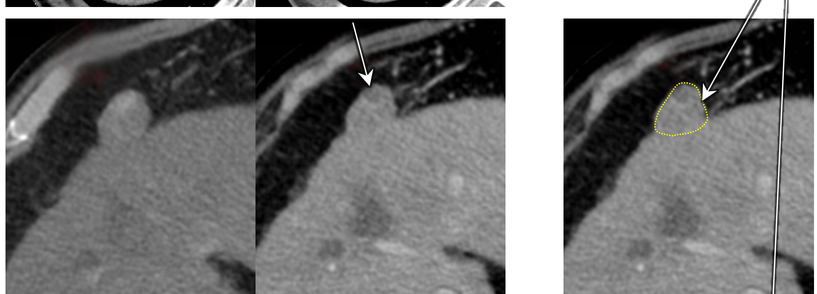


Nonperipheral “washout”:
Scattered (patchy, spotty)



Observation boundary drawn for clarity

Nonperipheral “washout”:
Nodule in nodule



Nonperipheral “washout”:
Mosaic

Nonperipheral “Washout”

RADLEX ID: N/A

Characterization (Cont’d)

Examples: MRI

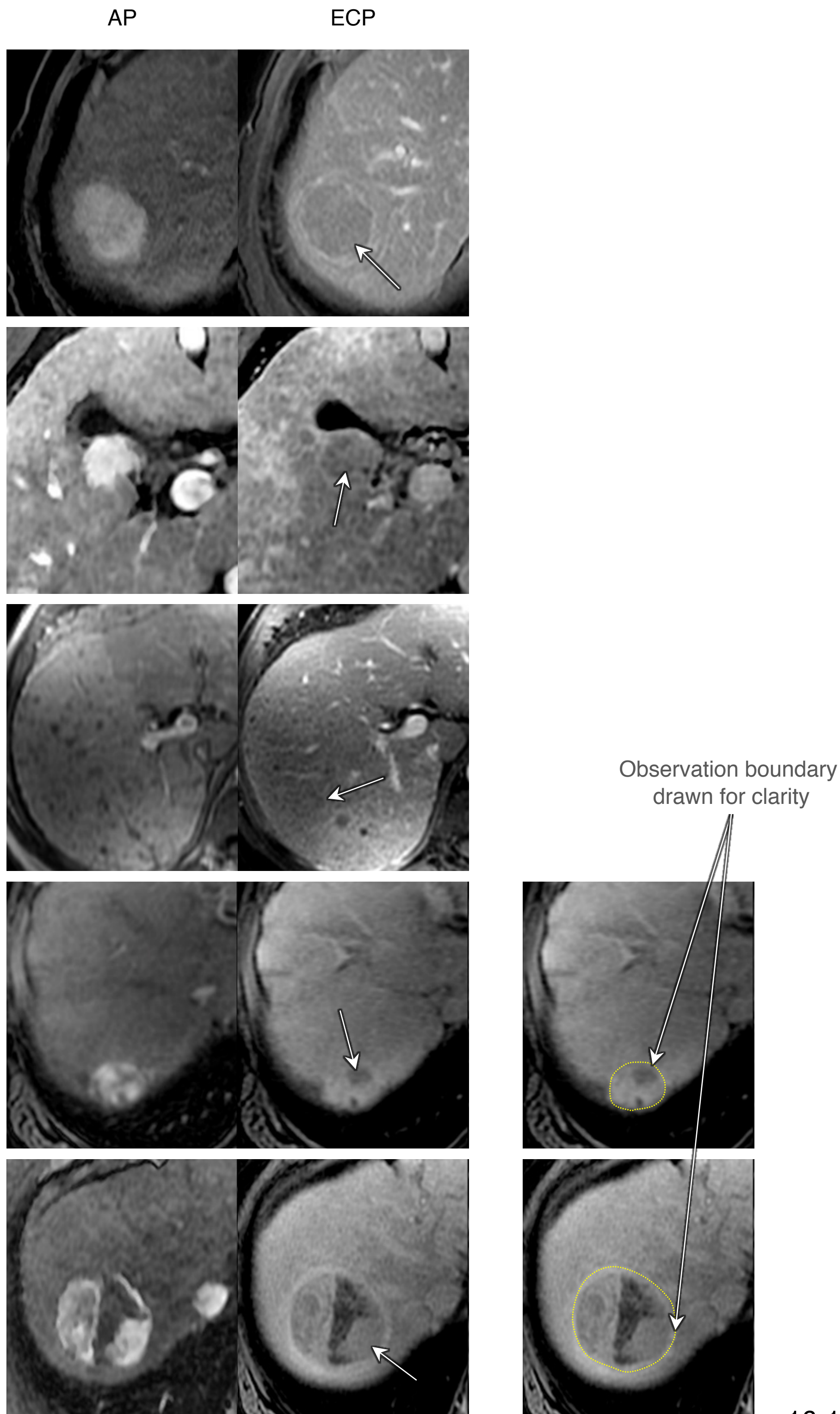
Nonperipheral “washout”:
Diffuse, homogeneous

Nonperipheral “washout”:
Diffuse, heterogeneous

Nonperipheral “washout”:
Scattered (patchy, spotty)

Nonperipheral “washout”:
Nodule in nodule

Nonperipheral “washout”:
Mosaic



Nonperipheral “Washout”

RADLEX ID: N/A

Characterization (Cont’d)

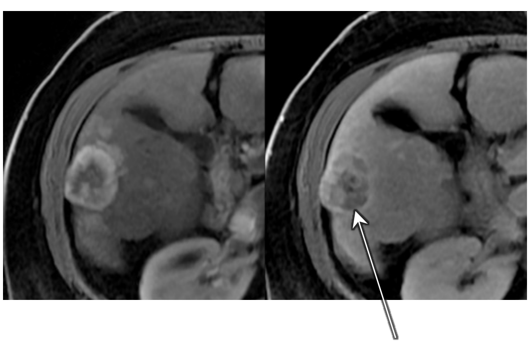
If unsure

If unsure about nonperipheral WO vs no WO, characterize as no WO
- *Rationale: LI-RADS imaging features are characterized as present only if there is certainty*

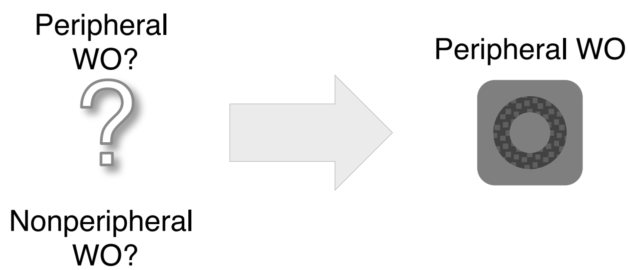
If unsure about peripheral WO vs nonperipheral WO, characterize as peripheral WO
- *Rationale: provides low threshold for alerting referrer to possibility of non-HCC malignancy*

Example: peripheral WO vs nonperipheral WO, characterize as nonperipheral WO

AP PVP



Peripheral WO vs. nonperipheral WO?



Nonperipheral "Washout"

RADLEX ID: N/A

Pitfalls & practical considerations

See page 16-108 for general "washout" pitfalls, which include optical illusion pitfalls, misinterpretation pitfalls, and detection pitfalls. Some specific examples are listed below.

- An enhancing "capsule" may produce the false perception or optical illusion of "washout", when "washout" is absent as confirmed by objective measurements. See page 16-115.
- Fat or iron (MRI) in an observation may create the appearance of "washout" when there is none. See page 16-117.
- "Washout" may be difficult to assess if the liver is darker than normal, due to steatosis (CT or MRI) or iron overload (MRI). See page 16-121. Subtraction images may help. See page 16-104.

Although nonperipheral "washout" is a major feature for HCC, its characterization is subjective and prone to inconsistency both within and between readers.

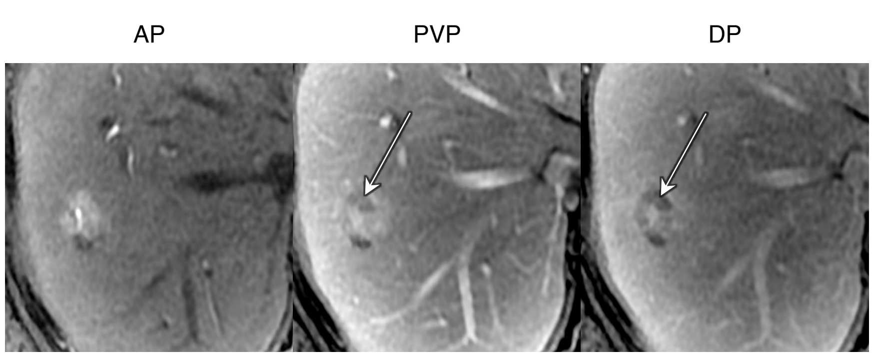
The presence of nonperipheral "washout" may be subtle. If subtle but unequivocal, then characterize as present.

There is no minimum size for application of nonperipheral "washout", rather its presence should be unequivocal in the radiologist's judgment.

Not all HCCs have "washout".

Some HCCs have peripheral "washout", rather than nonperipheral "washout"

Example: MRI



Path-proven atypical HCC with peripheral "washout"

This was categorized LR-M based on peripheral "washout". Biopsy indicated HCC

Nonperipheral “Washout”

RADLEX ID: N/A

Pitfalls & practical considerations (Cont’d)

Nonperipheral “washout” APHE is not specific for HCC and can be seen in a wide spectrum of other observations:

- atypical perfusion alterations
- dysplastic nodules
- small non-HCC malignancies

In particular, small iCCA (< 3 cm) may show nonperipheral “washout” (instead of their more typical peripheral “washout”), complicating their differentiation from HCC. See *page 16-132*.

The distinction between peripheral and nonperipheral “washout” is not always straightforward. If unsure, characterize as peripheral washout to maintain specificity of LR-5 for HCC. See *page 16-150*.

As stated on *page 16-138*, nonperipheral “washout” requires **BOTH** temporal reduction in enhancement **AND** darkness compared to liver in the postarterial extracellular phase. Observations that hyperenhance in the arterial phase and then become isointense or isoattenuating in the postarterial extracellular phase do not have “washout”, since they fail to meet the second requirement. Such observations are said to “fade”.

To assess “washout”, the enhancement of the observation should be compared to that of the adjacent liver parenchyma.

If the liver parenchyma visually consists of both nodules and fibrosis, then enhancement of the observation should be compared to that of the composite liver tissue (i.e., a visual average of the nodules and fibrosis). *See* *page 16-103*.

“Washout” can be in whole or in part. See *page 16-93*.

The part with “washout” must enhance to some degree in earlier phases but does not need to show APHE and does not need to correspond to the part with APHE:

- The part with “washout” may overlap completely with the part with APHE. See *page 16-94*.
- The part with “washout” may overlap somewhat with the part with APHE. See *page 16-94*.
- The part with “washout” may not overlap at all with the part with APHE. See *page 16-94*.

Nonperipheral "Washout"

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Using extracellular agents or gadobenate (see *pages 16-108, 16-109, 16-111*)**:**

Do: Characterize hyper (AP) → hypo (PVP) and/or hypo (DP) as "washout"

Do: Characterize iso (AP) → hypo (PVP) and/or hypo (DP) as "washout"

Do not: Characterize hyper (AP) → hyper (PVP) → iso (DP) as "washout"

Do not: Characterize hyper (AP) → iso (PVP) → iso (DP) as "washout" (this is termed "fade")

The combination of PVP and DP is more sensitive than PVP alone for detecting "washout". Hence, LI-RADS recommends routine DP imaging, not just PVP, when using ECA or gadobenate

---

Using gadoxetate (see *pages 16-110, 16-112*)**:**

Do: Characterize hyper (AP) → hypo (PVP) as "washout"

Do: Characterize iso (AP) → hypo (PVP) as "washout"

Do not: Characterize hyper (AP) → iso (PVP) → hypo (TP or HBP) as "washout"

Do not: Characterize iso (AP) → iso (PVP) → hypo (TP or HBP) as "washout"

Hypointensity in transitional or hepatobiliary phase does not qualify as "washout".

Nonperipheral "Washout"

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Gadoxetate-enhanced MRI presents many challenges in assessing "washout".

- Neither TP hypointensity nor HBP hypointensity are considered "washout".
- "Washout" should be assessed only during PVP, prior to TP and HBP.
- In individuals with normal hepatic function, brisk hepatocellular uptake of gadoxetate can cause substantial enhancement of the liver as early as the PVP; therefore, in at risk patients with relatively preserved hepatic function, hepatocyte uptake in the PVP potentially could result in a "pseudo-washout appearance".
- Hypointensity in the TP and/or HBP can be occur in non-hepatocellular lesions (metastases, hemangiomas, cholangiocarcinomas) due to lack of transporter expression in combination with strong enhancement of the liver parenchyma. Because they are not specific for HCC, TP and HBP hypointensity are ancillary features favoring malignancy, not major features of HCC.
- "Washout" may be difficult to detect in HCCs that express OATP.
  - Intracellular gadoxetate uptake by such HCCs in the PVP may counteract the effect of "washout" on signal intensity.
  - Due to their OATP expression, these HCCs tend to be hyperintense in the HBP.
  - A LR-5 category may be assignable depending on size and presence of APHE, threshold growth, and enhancing "capsule".
  - Ancillary features favoring malignancy are additional clues to the diagnosis but do not by themselves allow LR-5 categorization.
- Compared with other MR agents, gadoxetate disodium is less likely to depict nonperipheral "washout". See page 16-120.

Nonperipheral "Washout"

RADLEX ID: N/A

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Nonperipheral “Washout”

RADLEX ID: N/A

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Size

RADLEX ID: N/A

Definition

Largest outer-edge-to-outer-edge dimension of an observation

Synonyms

Diameter, dimension, long axis

Terminology

The term "size" is preferred over "diameter" as it is applicable to observations with shape other than spherical.

Applicable modalities

CT, MRI (all contrast agents)

Type of feature

Size is a stratifier that determines the number and combination of imaging features required for assigning LI-RADS categories assigned using the LI-RADS diagnostic table.

LI-RADS v2018 relies on two size thresholds:

- < 10 mm vs ≥ 10 mm
- < 20 mm vs ≥ 20 mm

Size ≥ 20 mm also precludes a solid distinctive nodule from being categorized LR-2. See *Chapter 15, page 26*.

Size

RADLEX ID: N/A

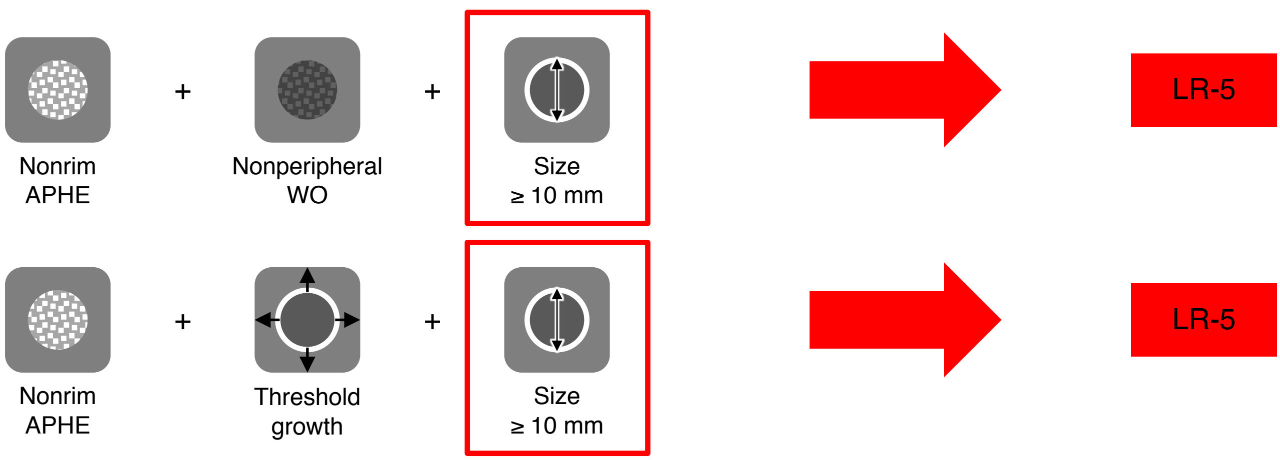
Effect on categorization

Size ≥ 10 mm is a major feature of HCC.

- In combination with two other major features, observations with size ≥ 10 mm can be categorized LR-5.

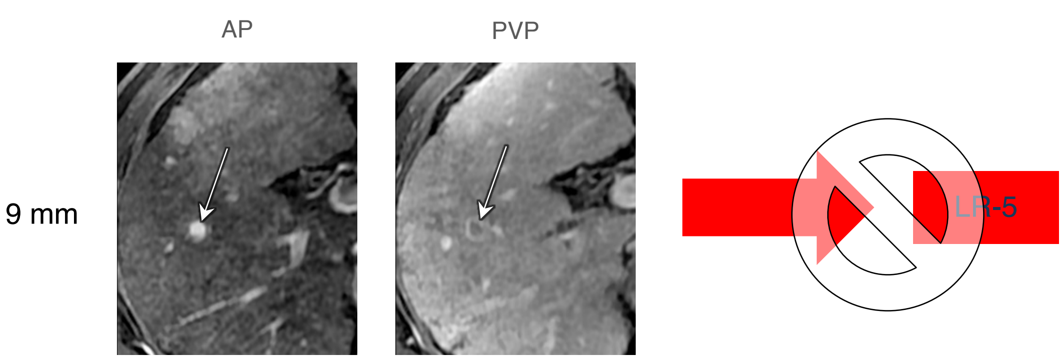
- These two combinations are:

    - Nonrim APHE + nonperipheral WO, **OR**
    - Nonrim APHE + threshold growth



Size ≥ 10mm is required for LR-5.

- Only observations 10 mm or larger can be categorized LR-5. As a corollary, size <10mm precludes LR-5 categorization.



Size

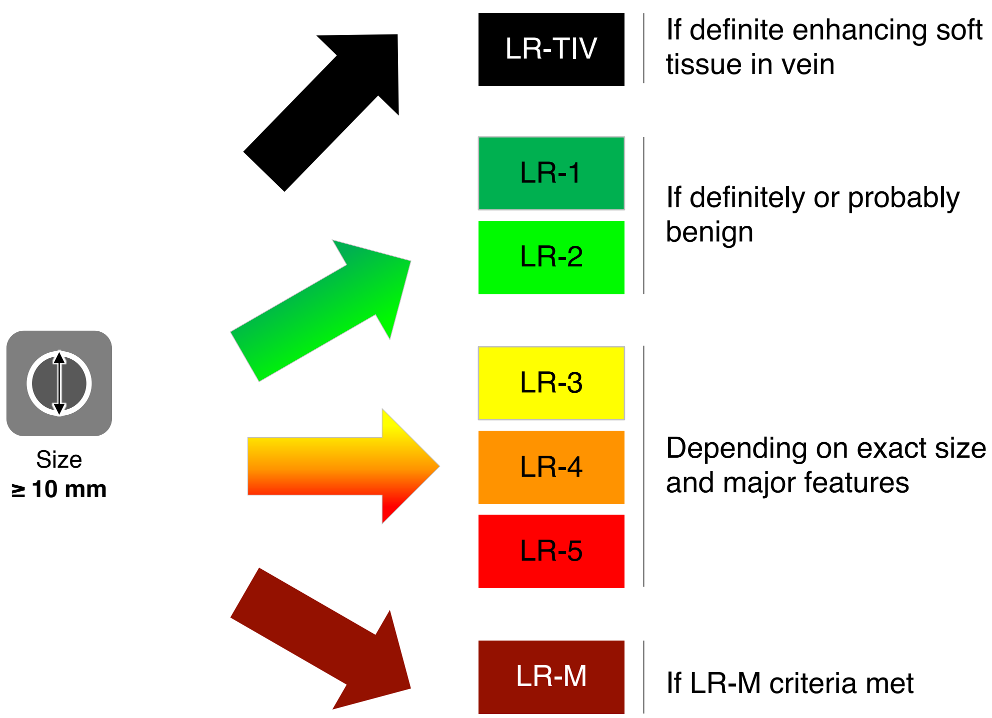
RADLEX ID: N/A

Effect on categorization (Cont'd)

Size ≥ 10 mm is not sufficient for LR-5.

- Observations ≥ 10mm *can* be other than LR-5.

- For example, observations ≥ 10 mm can be
  - LR-TIV (if enhancing soft tissue in vein)
  - LR-1 or LR-2 (if definitely or probably benign)
  - LR-M (if LR-M criteria met)
  - LR-3, LR-4, LR-5 (depending on exact size and major features)



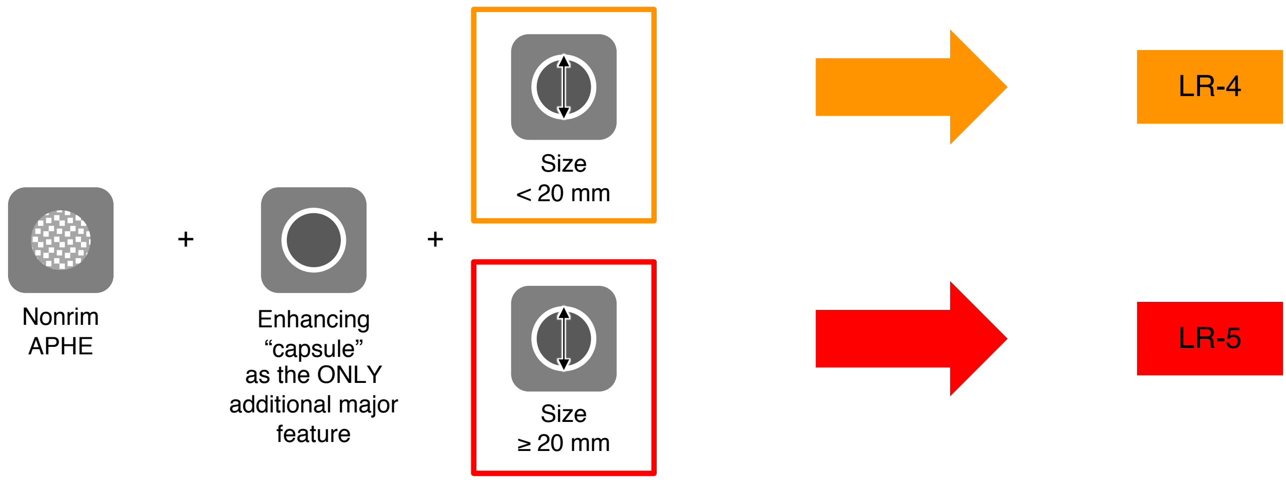
Size

RADLEX ID: N/A

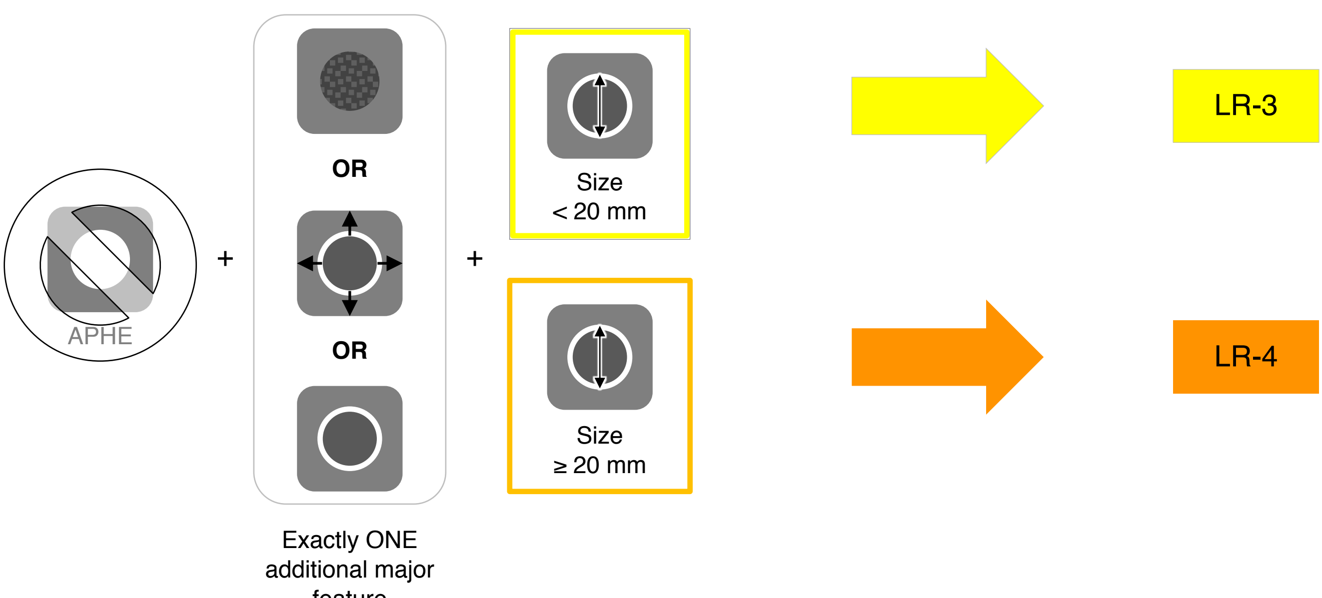
Effect on categorization (Cont'd)

Compared to size < 20 mm, size ≥ 20 mm can increase the category from LR-4 to LR-5 or from LR-3 to LR-4, depending on the presence of APHE, as explained below:

- For observations with nonrim APHE: size ≥ 20 mm allows observations with enhancing "capsule" as the only additional major feature to be categorized LR-5. Otherwise, they are categorized LR-4.



- For observations with no APHE: size ≥ 20 mm allows observations with only one additional major feature to be categorized LR-4. Otherwise, they are categorized LR-3.



Size

RADLEX ID: N/A

Biological basis

Size is an important imaging and biological feature of all observations, benign and malignant. In at-risk patients, the probability of HCC increases with size.

Pathology studies have shown that nodules < 10 mm in the cirrhotic liver are rarely malignant, with most being regenerative or dysplastic. Imaging observations < 10 mm are even less likely to be malignant since many of them are not true lesions at all, but rather vascular pseudolesions attributable to arterioportal shunts and other perfusion alterations. Hence, LI-RADS imposes a minimum 10 mm threshold for LR-5 categorization.

By comparison, a substantial proportion of observations ≥ 10 mm are malignant. Therefore, size ≥ 10 mm raises the probability of malignancy, allowing the definitive diagnosis of HCC to be made noninvasively by imaging, although stringent criteria must be applied to achieve high specificity.

Observations ≥ 20 mm are even more likely to be malignant, allowing the allowing the definitive diagnosis of HCC to be made noninvasively by imaging with slightly less stringent criteria.

In addition to its utility as a stratifier of HCC probability, size has a prognostic implications for predicting survival, and impacts the management decisions, including liver transplant eligibility.

Summary of evidence

Multiple studies have shown that size impacts imaging performance for the noninvasive diagnosis for HCC, as summarized by a meta-analysis published in 2018:

Size	Modality	Sensitivity (%)	Specificity (%)
< 10 mm	CT	48	69
	MRI with ECA	69	46
10 – 19 mm	CT	64	88
	MRI with ECA	70	87
≥ 20 mm	CT	79	90
	MRI with ECA	88	87

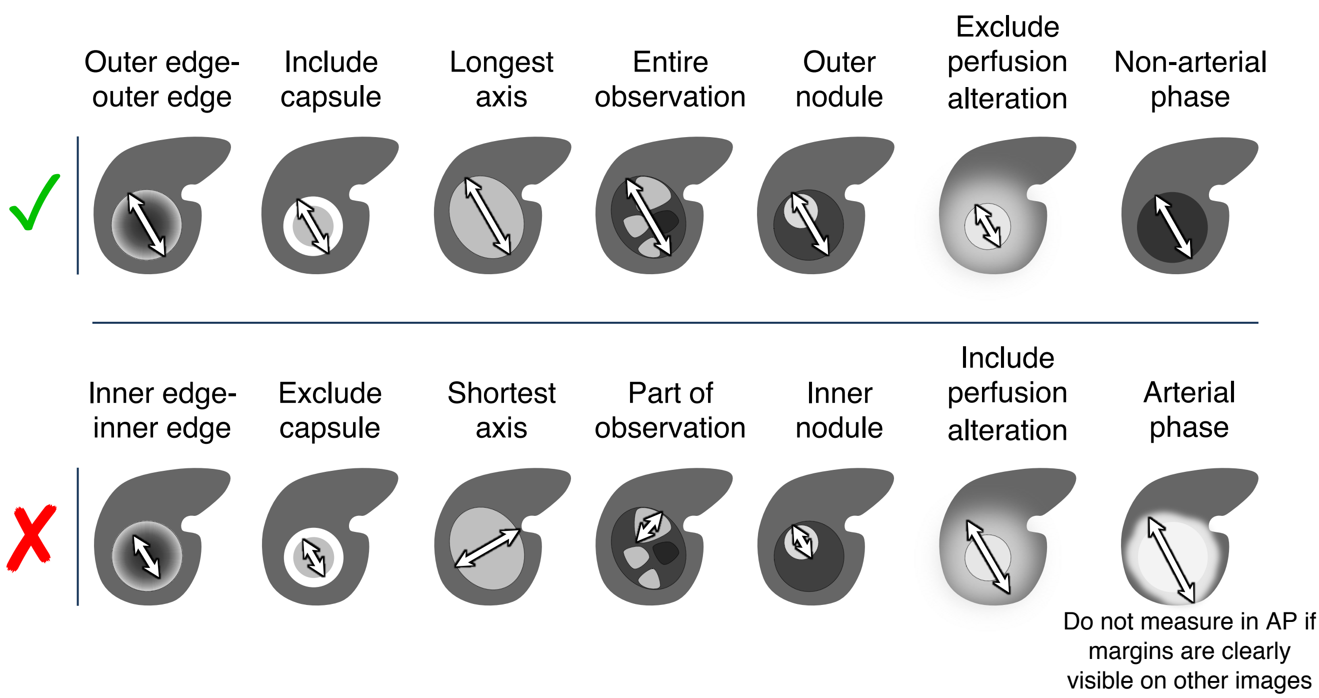
Reference: Roberts LR, Sirlin CB, Zaiem F, Almasri J, Prokop LJ, Heimbach JK, Murad MH, Mohammed K. Imaging for the diagnosis of hepatocellular carcinoma: A systematic review and meta-analysis. Hepatology. 2018 Jan;67(1):401-421.

Size

RADLEX ID: N/A

Characterization

- Size should be measured on an image in which the observation's margins are sharp, with no anatomic distortion.
- Size sometimes is measured best on coronal or sagittal images.
- "Capsule", if present, should be included in the measurement.
- Avoid measuring size on arterial phase if the observation margins are clearly visible on any other phase or sequence since including corona enhancement or other periobservation enhancement on arterial phase may cause size overestimation.



If unsure

Keep in mind:

- 10 and 20 mm thresholds stratify the assignment of LI-RADS categories (see *CT/MRI Diagnostic Table*).
- 10, 20, 30 and 50 mm thresholds are important in radiologic tumor staging (see *Chapter 10*).

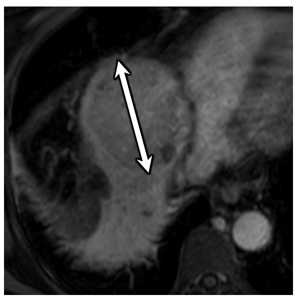
Size

RADLEX ID: N/A

Pitfalls & practical considerations

Size should be measured in the sequence, phase, and imaging plane in which the margins are most sharply demarcated and in which there is no anatomic distortion.

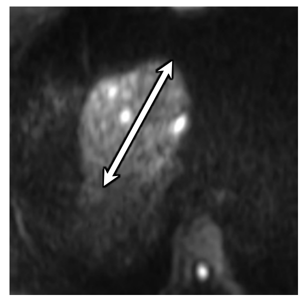
DP



Largest dimension on the DP = 70 mm.

There is no distortion, and the margins are sharply demarcated.

DWI b=800



Largest dimension on DWI = 80 mm.

The size is overestimated due to geometric distortion.

Size

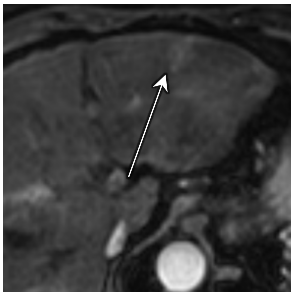
RADLEX ID: N/A

Pitfalls & practical considerations

Size is applicable to masses only and should not be applied to pseudolesions, such as vascular shunts.

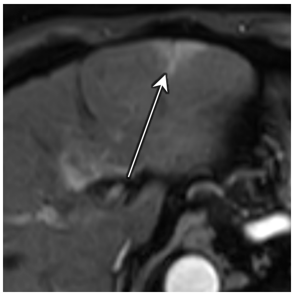
Rationale: Conceptually, growth refers to enlargement of a mass by spreading or expansion. Nonmass lesions like focal fat deposition may enlarge due to deposition of fat in adjacent hepatocytes but this does not represent spreading or expansion of the previously steatotic hepatocytes. More importantly, this provision preserves specificity for HCC by preventing attribution of growth to nonmass benign processes such as arterial perfusion alterations which may appear larger on one exam than on a prior due to changes in arterial phase timing or other factors. The provision that growth only applies to masses prevents false categorization of these benign vascular pseudolesions as LR-5.

AP: May 2009



Transient hepatic intensity difference (THID) measures 11 mm.

AP: April 2018



THID measures 20 mm. The change in size is due to difference in timing of the images, and not due to expansion of abnormal cells.

Size

RADLEX ID: N/A

Pitfalls & practical considerations

If margins are sharply demarcated on more than one sequence or phase, measurement should not be performed in the arterial phase (AP), as the apparent size on AP is variable, depending on the exact timing of image acquisition.

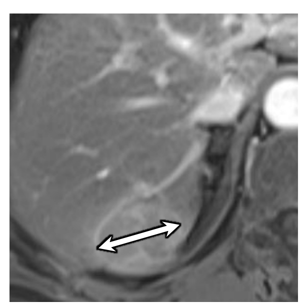
AP

Size measured on AP is measured as 27mm due to summation with corona

PVP

Size is more accurately measured on PVP as 23 mm

Size measured on AP is measured as 53 mm due to summation with corona



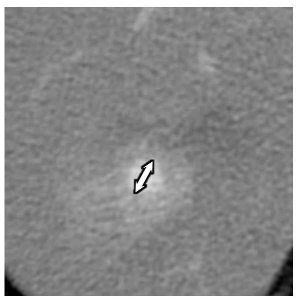
Size is more accurately measured on PVP as 38 mm

Size

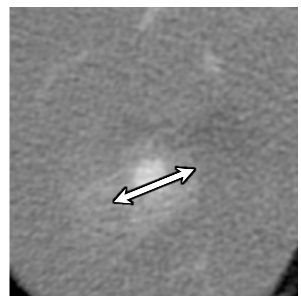
RADLEX ID: N/A

Pitfalls & practical considerations

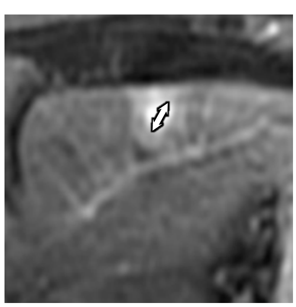
If an observation is surrounded by or is contiguous with a perfusion alteration, the perfusion alteration should not be included in the measurement.



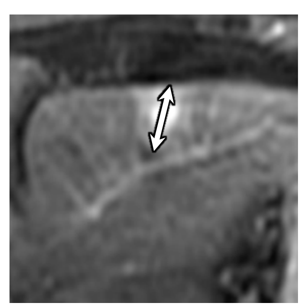
Measurement excludes perfusion alteration



Measurement includes perfusion alteration



Measurement excludes perfusion alteration



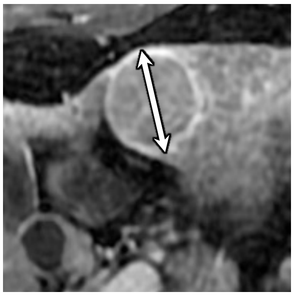
Measurement includes perfusion alteration

Size

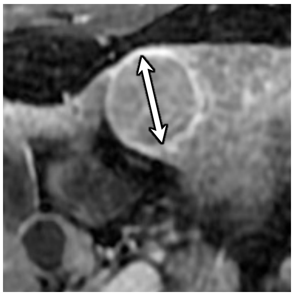
RADLEX ID: N/A

Pitfalls & practical considerations

If "capsule" is present, it should be included in the measurement.

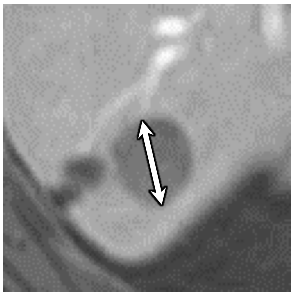


Measurement
includes "capsule"

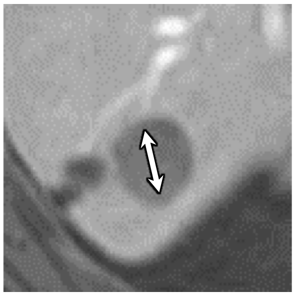


Measurement
excludes "capsule"

Measurement should extend from outer edge to outer edge.



Measurement
extends outer
edge to outer edge



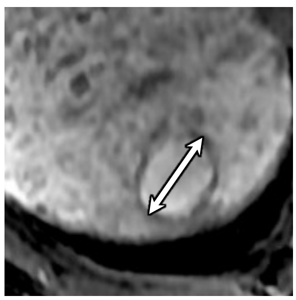
Measurement
does not extend
outer edge to outer
edge

Size

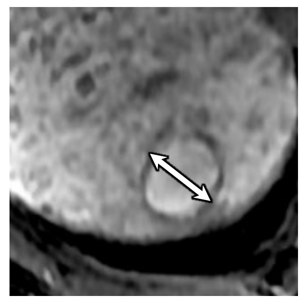
RADLEX ID: N/A

Pitfalls & practical considerations

Size should be measured along the largest dimension of the observation.



Measurement is along the longest axis



Measurement is along the shortest axis

Size

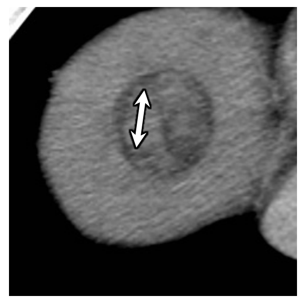
RADLEX ID: N/A

Pitfalls & practical considerations

For observations with nodule-in-nodule or mosaic architecture, include the entire mass in the measurement, not just the internal nodule(s).

✓

Measurement includes the entire observation



✗

Measurement includes one of the internal nodules only

✓

Measurement includes the entire observation

✗

Measurement includes the internal nodule only

Size

RADLEX ID: N/A

References

Becker-Weidman DJ, Kalb B, Sharma P, et al. Hepatocellular carcinoma lesion characterization: single-institution clinical performance review of multiphase gadolinium-enhanced MR imaging--comparison to prior same-center results after MR systems improvements. Radiology. 2011;261(3):824-33.

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Figueras J, Ibanez L, Ramos E, Jaurrieta E, Ortiz-de-Urbina J, Pardo F, et al. Selection criteria for liver transplantation in early-stage hepatocellular carcinoma with cirrhosis: results of a multicenter study. Liver transplantation : official publication of the American Association for the Study of Liver Diseases and the International Liver Transplantation Society. 2001;7(10):877-83.

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Size

RADLEX ID: N/A

References (Cont'd)

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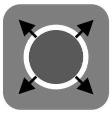
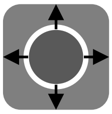
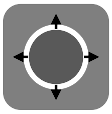
Growth and its Subtypes

Feature	Definition	*Page*
Growth 	Unequivocal size increase of a mass (i.e., not attributable to measurement imprecision or error, differences in technique, or interval hemorrhage) Applies only to masses; does not apply to non-mass lesions such as focal fat deposition or to pseudolesions such as benign perfusion alterations	*16-173*
Growth subtypes		
Threshold growth 	≥ 50% size increase of a mass in ≤ 6 months • Measure on same phase, sequence, and plane on serial exams if possible. • Apply threshold growth *only* if there is a prior CT or MRI exam of sufficient quality and appropriate technique to gauge if growth has occurred. Do not assess threshold growth by comparing to prior US or CEUS exams.	*16-175*
Subthreshold growth 	Unequivocal size increase of a mass, less than threshold growth • Measure on same phase, sequence, and plane on serial exams if possible. • Apply subthreshold growth *only* if there is a prior CT or MRI exam of sufficient quality and appropriate technique to gauge if growth has occurred. Do not assess threshold growth by comparing to prior US or CEUS exams. • Includes an unequivocally new mass of any size compared to any prior CT or MRI.	*16-259*

Growth

RADLEX ID: RID39547

Definition

Unequivocal size increase of a mass (i.e., not attributable to measurement imprecision or error, differences in technique, or interval hemorrhage)

Synonyms

Interval growth, progression, size increase, diameter increase

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Terminology

The term growth is preferred as it is commonly used and concise.

Applicable modalities

CT, MRI (all contrast agents)

For discussion of growth on CEUS, see CEUS manual.(pending)

Type of feature

Threshold growth (TG): Major feature of HCC

Subthreshold growth: Ancillary feature favoring malignancy

If unsure

If unsure that growth is present, do not categorize as growth

If unsure of TG vs subthreshold growth, characterize as subthreshold growth

---

Effect on categorization

Effect on characterization depends on degree of growth and presence of other imaging features. For further discussion, see sections on threshold growth *(page 16-175)* and subthreshold growth *(page 16-259)*.

Growth

RADLEX ID: RID39547

Characterization

Threshold growth and subthreshold growth are mutually exclusive subtypes.

- If size increase of the mass is ≥ 50% in ≤ 6 months, characterize as threshold growth, NOT subthreshold growth. See page 16-178.

For more information on characterization of

- Threshold growth, see page 16-178.
- Subthreshold growth, see page 16-261.

Pitfalls, biological basis, evidence

See sections threshold growth (page 16-175) and subthreshold growth (page 16-259).

Threshold Growth

RADLEX ID: RID43350

Definition

Size increase of a mass by ≥ 50% in ≤ 6 months

Synonyms

Growth by 50% or more (terminology used by OPTN)

Terminology

The term “threshold growth” refers to size increase of observation beyond the above threshold and within the specified time frame. Rationale: this threshold is used by OPTN and is based on indirect evidence from tumor volume doubling time of untreated HCCs reported in the literature.

Applicable modalities

CT, MR (all contrast agents)

Type of feature

Major feature for HCC, but is neither required nor sufficient for LR-5. *See page 16-176*.

Effect on categorization

Observations with TG may be categorized LR-3, LR-4, LR-5, or LR-TIV, depending on presence of other features (see *CT/MRI Diagnostic Table*).

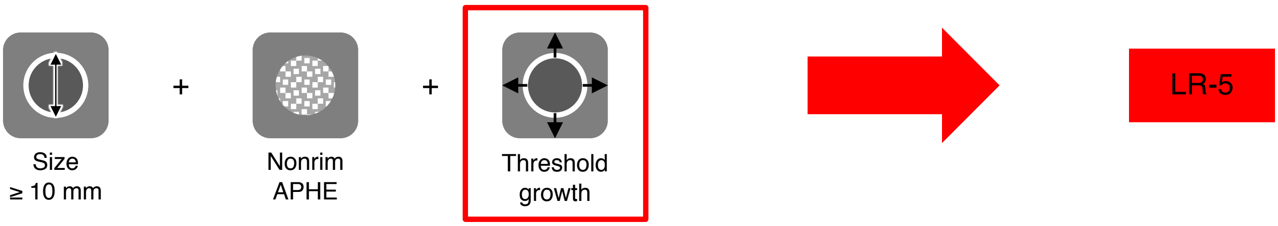
Threshold Growth

RADLEX ID: RID43350

Effect on categorization (Cont'd)

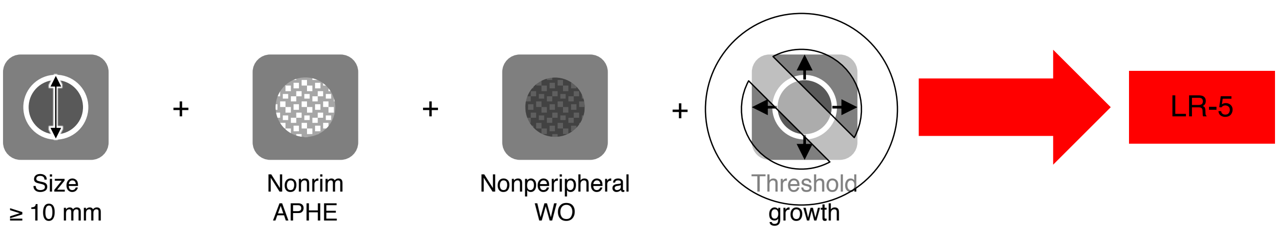
Threshold growth is a major feature of HCC.

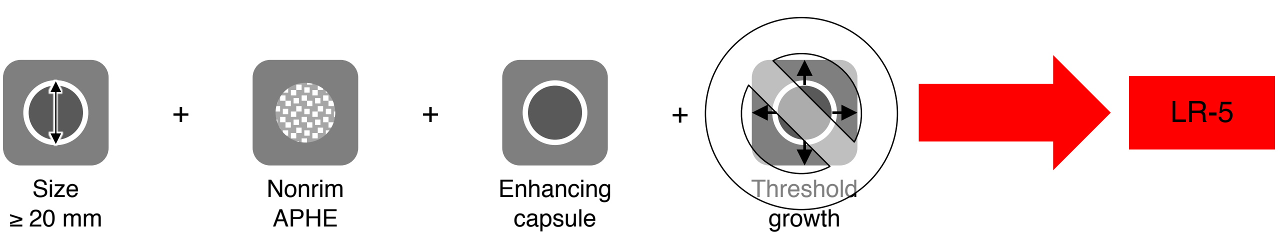
In combination with two other major features (nonrim APHE, size ≥ 10 mm), observations with threshold growth can (and usually should) be categorized LR-5. However, threshold growth is neither required nor sufficient for LR-5:



Threshold growth is not required for LR-5.

Observations without threshold growth *can* be LR-5. For example, the following observations are categorized LR-5 despite lacking threshold growth:





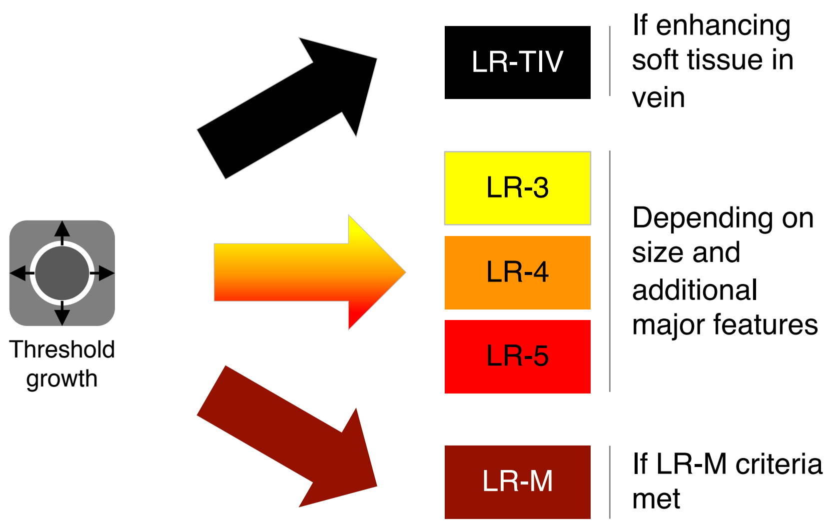
Threshold Growth

RADLEX ID: RID43350

Effect on categorization (Cont'd)

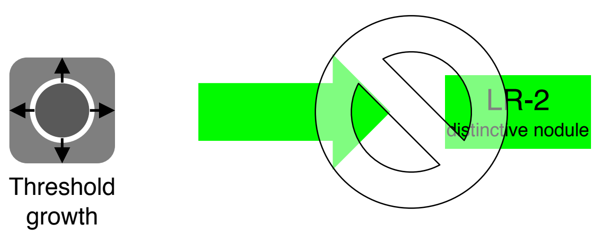
Threshold growth is not sufficient for LR-5.

- Observations with threshold growth *can* be other than LR-5.
- For example, observations with threshold growth can be
  - LR-TIV (if enhancing soft tissue in vein)
  - LR-3, LR-4, LR-5 (depending on size and additional major features)
  - LR-M (if LR-M criteria met)



Threshold growth excludes LR-2 distinctive nodule.

The presence of threshold growth excludes LR-2 distinctive nodule from consideration.



By definition, LR-2 distinctive nodules cannot have any major feature of HCC.

Threshold Growth

RADLEX ID: RID43350

Biological basis

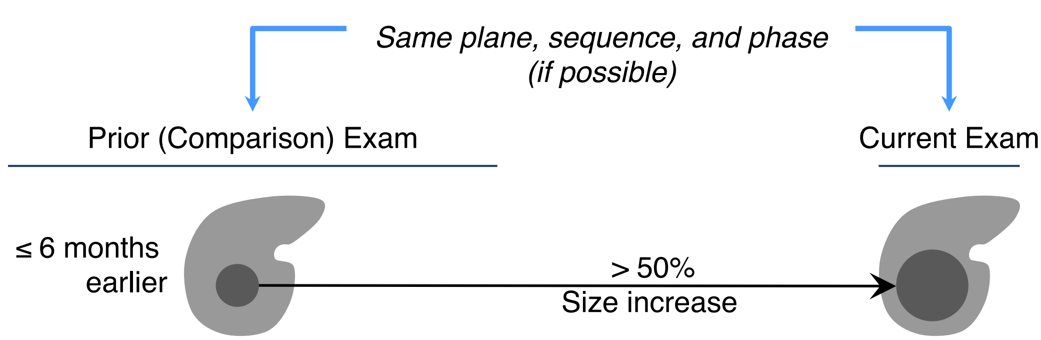
Growth is an indicator of malignancy. Physiologically, tumor growth rate is an indicator of the biological potential of a tumor and its blood supply. While benign lesions tend to remain stable or grow slowly over time, malignant tumors grow more rapidly. Further, growth rate reflects the degree of de-differentiation of malignant tumors, as moderately- and poorly-differentiated HCCs tend to grow more rapidly than well-differentiated HCCs. Since all malignant tumors grow, however, growth is not specific for HCC in particular.

Summary of evidence

- Inclusion of TG in the LI-RADS algorithm was based on biological plausibility, expert opinion, and a desire to maintain consistency with OPTN, which recognizes "growth by 50% or more documented on serial CT or MR images obtained ≤ 6 months apart" as a feature of HCC.
- The criteria of TG are based on data on doubling time of small HCCs, a size group for which threshold growth is more likely to be needed for LR-5 categorization.
- HCCs < 2 cm at presentation have a mean tumor volume doubling time of around 210 days.
- Also supporting the concept of threshold growth is that growing "hypovascular" (i.e., no APHE) nodules have a higher incidence of future "hypervascularization" (i.e., development of APHE).
- 16% of US-detected large RNs and 33% of US-detected large DNs grow by ≥ 50% during sonographic follow-up.
- While there is a lack of prospective studies validating the diagnostic accuracy of the specified growth threshold (≥ 50% in ≤ 6 months), biological plausibility and indirect evidence suggest that growth is a feature of malignancy and helps differentiate HCC from benign entities.

Characterization

Assessment of TG should be performed by comparing the observation size between the current and the prior examination. If possible, the assessment should be done using the same plane, sequence, and phase.



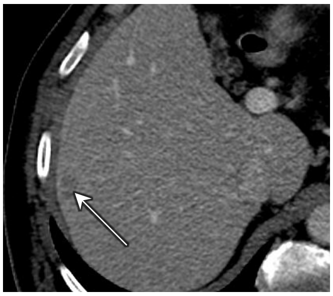
Threshold Growth

RADLEX ID: RID43350

Characterization (Cont'd)

Example: CT

Initial CT



Size: 14mm

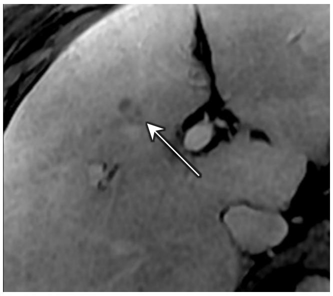
6 month follow-up CT

Size: 24mm

71% size increase
in 6 mo = TG

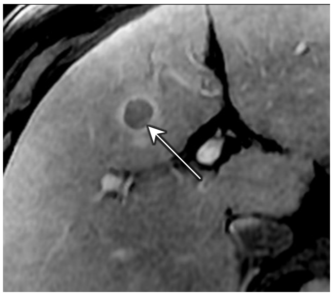
Example: MRI

Initial MRI



Size: 12mm

4 month follow-up MRI



Size: 20mm

67% size increase
in <6 mo = TG

Threshold Growth

RADLEX ID: RID43350

If unsure

If unsure that TG is present, do not characterize as TG.

If unsure that growth is TG vs subthreshold growth, characterize as subthreshold growth.

Pitfalls & practical considerations

- TG is not applicable if there are no comparable prior studies.
- The observation must have been seen on a previous exam to demonstrate TG.
- Growth should be assessed on images acquired in the same plane and, if possible, the same phase or sequence.
- If margins are sharply demarcated on more than one sequence or phase, do not measure in the arterial phase.
- Cross modality comparison (CT vs MR) should be used with caution to assess TG.
- CEUS and US measurements cannot be used to classify growth as TG because of potential foreshortening of the observation size.

Some dysplastic nodules may grow and potentially could meet the threshold growth criterion. These would be categorized LR-3 or higher, depending on other features.

Cysts and hemangiomas can grow in patients without underlying liver disease, but rarely grow in patients with cirrhosis.

While threshold growth does not completely preclude categorization of observations as LR-1 or LR-2, it would be unlikely for a benign lesion such as a cyst or hemangioma to grow fast enough to meet the definition of threshold growth.

References

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Threshold Growth

RADLEX ID: RID43350

References (Cont'd)

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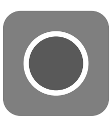
Subthreshold Growth

RADLEX ID: N/A

See *page 16-259*.

Capsule Appearance and its Subtypes

RADLEX ID:

Feature	Definition	*Page*
"Capsule" 	Smooth, uniform, sharp border around most or all of an observation, unequivocally thicker or more conspicuous than fibrotic tissue around background nodules	*16-184*
"Capsule" subtypes		
Enhancing "capsule" 	Subtype of capsule appearance visible as an enhancing rim in portal venous phase, delayed phase, or transitional phase.	*16-187*
Nonenhancing "capsule" 	Subtype of capsule appearance NOT visible as an enhancing rim. Includes smooth, uniform, sharp *nonenhancing* border visible in arterial phase, portal venous phase, delayed phase, or transitional phase. Also includes smooth, uniform, sharp border on unenhanced CT images, unenhanced T1W images, T2W images, T2*W images, or, if obtained, DW images, fat fraction maps, or R2* maps. If a border is visible on enhanced and unenhanced images, characterize as enhancing "capsule". See *page 16-193*.	*16-309*

Capsule Appearance (“Capsule”)

RADLEX ID: RID39439

Definition

Smooth, uniform, sharp border around most or all of an observation, unequivocally thicker or more conspicuous than fibrotic tissue around background nodules.

Capsule appearance or “capsule” has two subtypes:

- Enhancing “capsule”: see page 16-184.
- Nonenhancing “capsule”: see page 16-309.

If a “capsule” is visible as both an enhancing rim AND on other images as a nonenhancing rim, characterize as enhancing “capsule”, NOT as nonenhancing “capsule”. See page 16-193.

Synonyms

Capsule, tumor capsule, pseudocapsule, fibrous capsule are synonyms for capsule appearance.

Capsular enhancement and delayed enhancing rim are synonyms for enhancing capsule appearance, a subtype of capsule appearance.

Terminology

The term, capsule appearance or “capsule”, is preferred, as the radiologic “capsule” does not always represent a true tumor capsule and may instead represent a pseudocapsule.

A pseudoocapsule is a radiologic term that refers to the imaging appearance of a capsule in the absence of a true capsule at pathology.

The distinction between true tumor capsule and pseudocapsule can only be made at pathology. For more information on pseudocapsule, see page 16-185.

Applicable modalities

CT, MRI

Type of feature

Depends on “capsule” subtype:

- Enhancing “capsule”: Major feature of HCC
- Nonenhancing “capsule”: Ancillary feature favoring HCC

Capsule Appearance ("Capsule")

RADLEX ID: RID39439

Effect on categorization

Effect on categorization depends on "capsule" subtype and on presence of other imaging features.

Presence of "capsule" excludes LR-1 or LR-2 categorization.

- One exception: at radiologist's discretion, an LR-3 observation with "capsule" can be downgraded to LR-2 by ancillary features favoring benignity such as ≥ 2-year stability or spontaneous size reduction.

For further discussion, see sections on enhancing "capsule" (page 16-188) and nonenhancing "capsule" (page 16-309).

Biological basis

A "capsule" detected on imaging may reflect

- A true histologic tumor capsule. This is a fibrous layer around an HCC nodule elaborated by parenchymal mesenchymal cells in response to mechanical and chemical stimuli induced by the expanding tumor. The outer layer of a true capsule is made of prominent sinusoids.

- A pseudocapsule. This comprises a combination of perilesional sinusoids, fibrous tissue, and compressed liver parenchyma. While it may resemble a true tumor capsule at imaging, it is not.

Pseudocapsule and true capsule cannot be distinguished on imaging.

Since capsule formation is associated with expansile tumor growth, "capsules" are characteristic imaging features of progressed HCCs. Not all progressed HCCs are associated with tumor capsules, however. HCCs in highly fibrotic livers are more likely to have tumor capsules than HCCs in less fibrotic livers.

Capsule formation is rare in HCC precursor lesions which tend to have replacing rather than expansile growth.

Capsule formation is rare in iCCAs which tend to have locally invasive growth rather than expansile growth.

Capsule Appearance (“Capsule”)

RADLEX ID: RID39439

Summary of evidence

For enhancing “capsule”: see page 16-191.

For nonenhancing “capsule”: see page 16-310.

If unsure

If unsure that “capsule” is present, do not characterize as “capsule”.

If unsure that “capsule” is enhancing vs. nonenhancing, characterize as nonenhancing “capsule”.

Characterization

Enhancing “capsule” and nonenhancing “capsule” are mutually exclusive subtypes.

- If a border is visible on enhanced and unenhanced images, characterize as enhancing “capsule”, NOT nonenhancing “capsule”. See page 16-193.

For more information on characterization of

- Enhancing “capsule”, see page 16-192.
- Nonenhancing “capsule”, see page 16-310.

Pitfalls & practical considerations

A rim of HBP hyperenhancement (HBP hyperintense rim) does not qualify as “capsule”. Such rims are not well understood but presumably reflect a layer of hepatocellular tissue around the observation that – due to due to increased uptake, reduced excretion, or both – accumulates more contrast agent than background liver.

For additional pitfalls & practical considerations, see sections on enhancing “capsule” (page 16-196) and nonenhancing “capsule” (page 16-312).

References

For enhancing “capsule”, see page 16-202.

For nonenhancing “capsule”, see page 16-313.

Enhancing "Capsule"

RADLEX ID: N/A

Definition

Subtype of capsule appearance visible as enhancing rim in portal venous phase, delayed phase, or transitional phase

Synonyms

Capsule, tumor capsule, pseudocapsule, fibrous capsule, capsular enhancement, delayed enhancing rim

Terminology

The term, enhancing capsule appearance or enhancing "capsule", is preferred, as the rim of enhancement does not always represent a true tumor capsule and may instead represent a pseudocapsule.

A pseudocapsule is a radiologic term that refers to the imaging appearance of a capsule in the absence of a true capsule at pathology.

The distinction between true tumor capsule and pseudocapsule can only be made at pathology. For more information on pseudocapsule, see *page 16-185*.

Applicable modalities

CT, MRI

Type of feature

Major feature of HCC

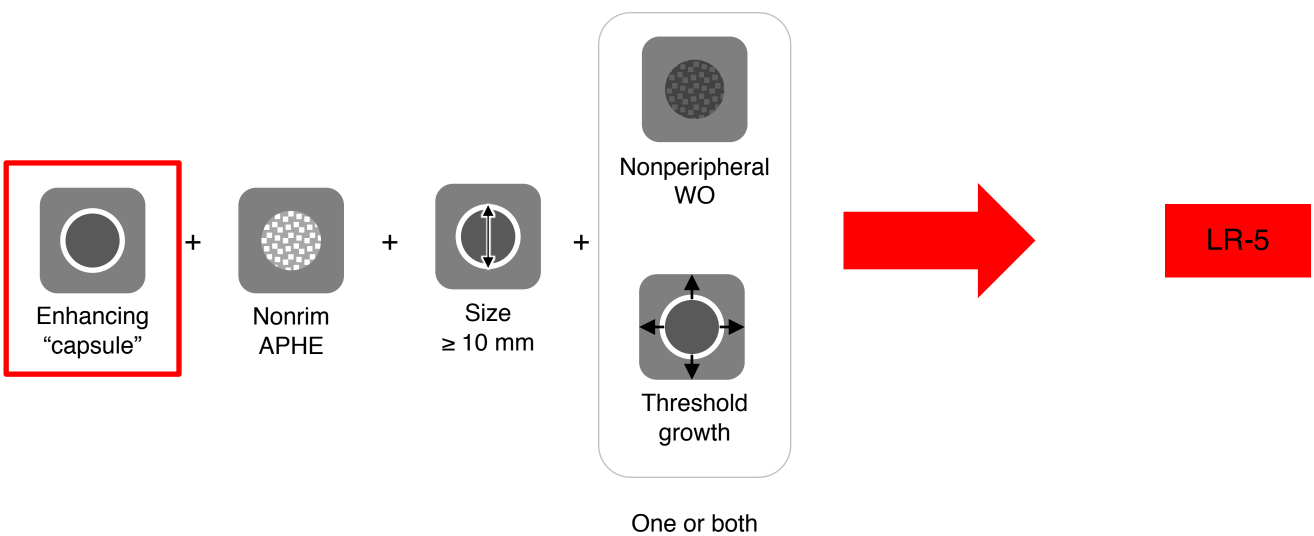
Enhancing "Capsule"

RADLEX ID: N/A

Effect on categorization

Enhancing "capsule" is a major feature of HCC.

In combination with other major features, observations with enhancing "capsule" can be categorized LR-5:



However, enhancing "capsule" is neither required nor sufficient for LR-5, as discussed on next two pages.

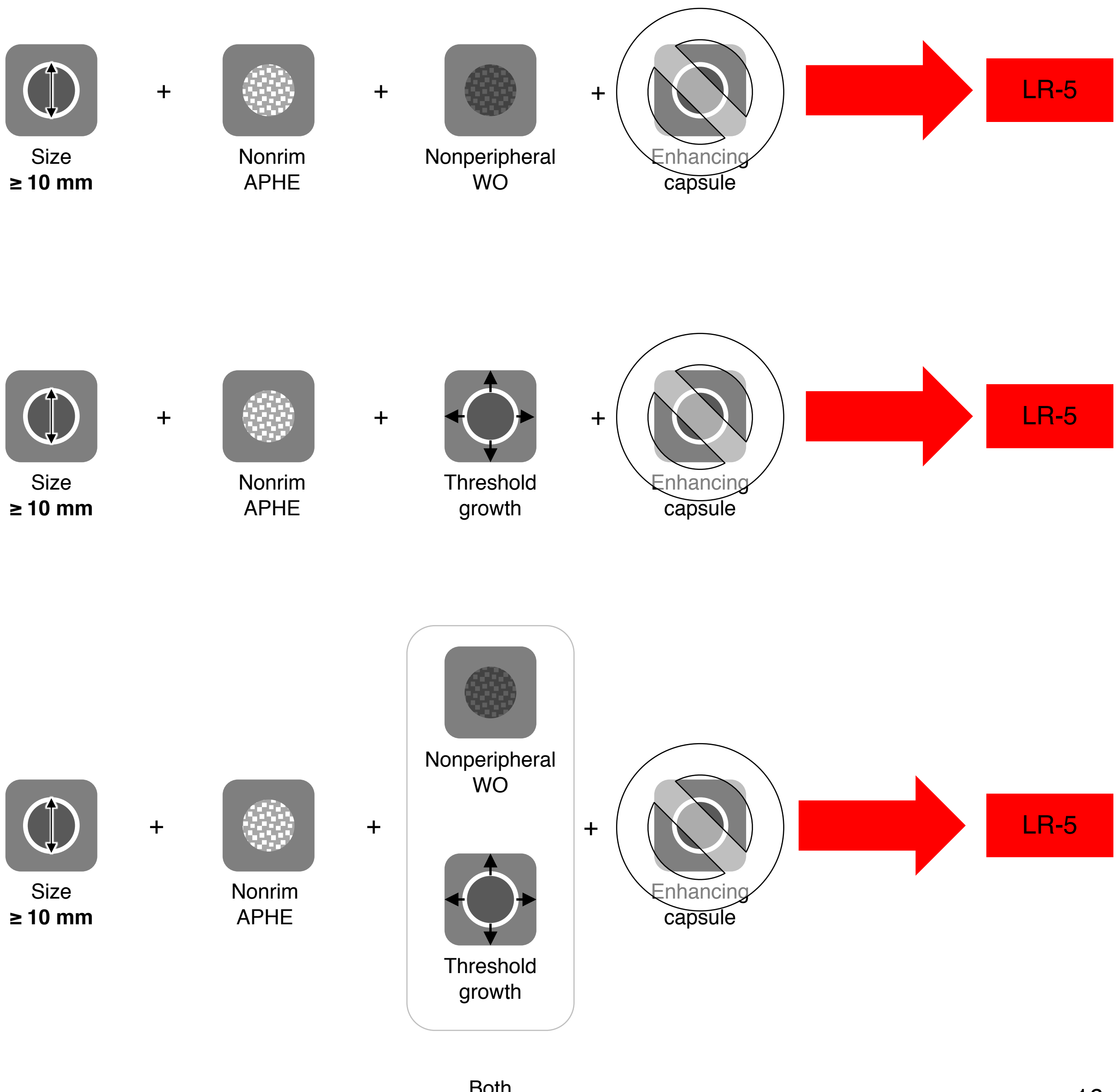
Enhancing "Capsule"

RADLEX ID: N/A

Effect on categorization (Cont'd)

Enhancing "capsule" is a not required for LR-5.

Depending on combination of other major features, observations without enhancing "capsule" can be categorized LR-5.



Enhancing "Capsule"

RADLEX ID: N/A

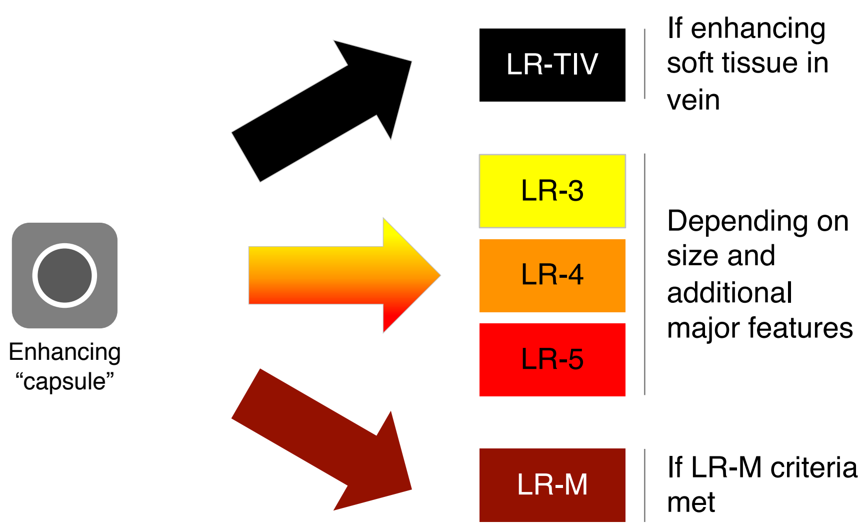
Effect on categorization (Cont'd)

Enhancing "capsule" is not sufficient for LR-5.

Observations with enhancing "capsule" *can* be other than LR-5.

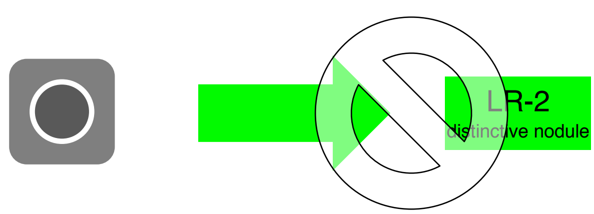
For example, observations with enhancing "capsule" can be

- LR-TIV (if there is enhancing tissue in vein)
- LR-3, LR-4, LR-5 (depending on size and additional major features)
- LR-M (if features of LR-M are present)



Enhancing "capsule" excludes LR-1 and LR-2.

The presence of "capsule" excludes LR-1 or LR-2 categorization from consideration.



- One exception: at radiologist's discretion, an LR-3 observation with "capsule" can be downgraded to LR-2 by ancillary features benignity such as ≥ 2-year stability or spontaneous size reduction.

Enhancing “Capsule”

RADLEX ID: N/A

Biological basis

An enhancing “capsule” may reflect

- A true histologic tumor capsule. This is a fibrous layer around an HCC nodule elaborated by parenchymal mesenchymal cells in response to mechanical and chemical stimuli induced by the expanding tumor. The outer layer of a true capsule is made of prominent sinusoids.
- A pseudocapsule. This comprises a combination of perilesional sinusoids, fibrous tissue, and compressed liver parenchyma. While it may resemble a true tumor capsule at imaging, it is not.

Regardless of type, the blood supply to the “capsule” is mainly from the portal venous system. This feature, along with the presence of peripheral prominent sinusoids, explains the delayed enhancement on portal venous, delayed, or transitional phases.

Pseudocapsule and true capsule cannot be distinguished on imaging.

Since capsule formation is associated with expansile tumor growth, “capsules” are characteristic imaging features of progressed HCCs. Not all progressed HCCs are associated with tumor capsules, however. HCCs in highly fibrotic livers are more likely to have tumor capsules than HCCs in less fibrotic livers.

Capsule formation is rare in HCC precursor lesions which tend to have replacing rather than expansile growth.

“Capsules” are uncommon in iCCAs which tend to have locally invasive growth rather than expansile growth.

Summary of evidence

Radiology evidence:

- Single-center studies have shown that enhancing capsule appearance has high specificity (86-96%) for HCC, which justifies the use of “capsule” as a major feature of HCC.
- Enhancing “capsule” has low sensitivity (42-64%) for HCC, however, in these same studies.
- Reader agreement for enhancing “capsule” tends to be fair to substantial (kappa 0.37 to 0.67; intraclass correlation coefficient 0.84, 95% CI 0.80-0.87).

Other considerations: LI-RADS seeks to maintain concordance with OPTN, which recognizes enhancing capsule appearance as a criterion for HCC. Note that OPTN uses the synonymous term “delayed enhancing term” rather enhancing “capsule”.

Enhancing “Capsule”

RADLEX ID: N/A

Characterization

Characterize on

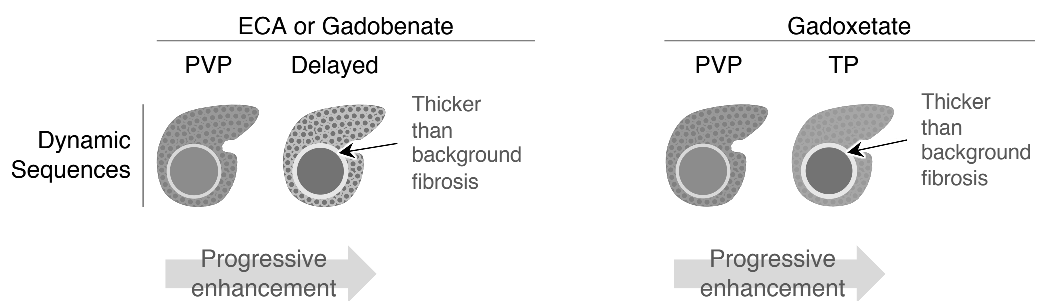
- PVP or DP if an extracellular agent or gadobenate is given
- PVP or TP if gadoxetate is given
  - Unlike “washout”, which must be characterized in PVP only if gadoxetate is given, enhancing “capsule” may be characterized in PVP, TP, or both.

Enhancing “capsule” is present if **BOTH**:

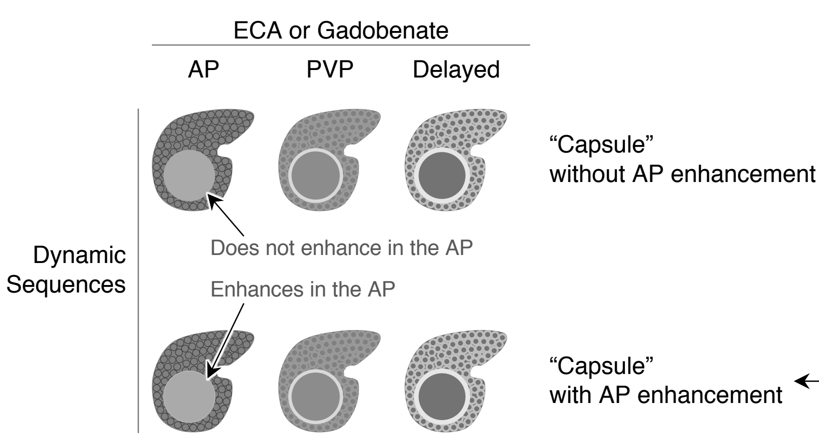
- There is a smooth, uniform, sharp border around most or all of an observation, unequivocally thicker or more conspicuous than fibrotic tissue around background nodules

  AND

- The rim progressively enhances from the PVP to the DP or TP



The “capsule” may or may not enhance in the arterial phase.



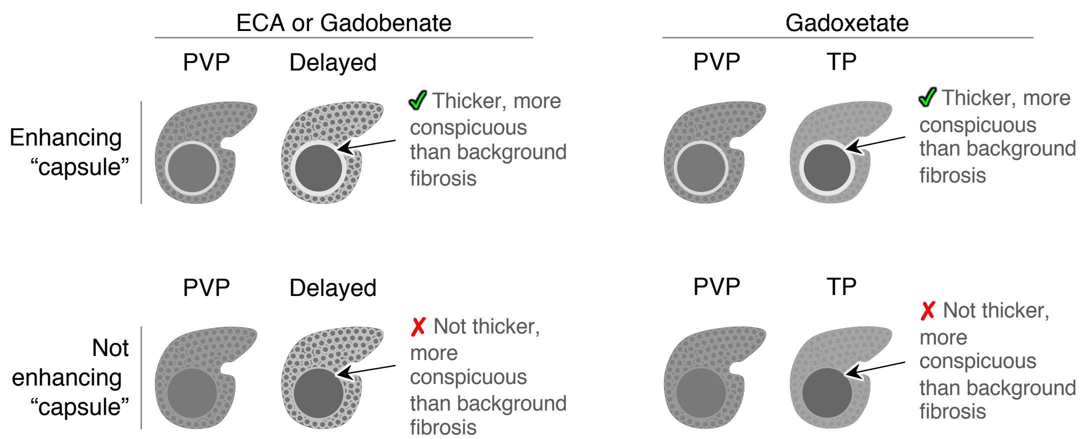
⚠ The enhancement of the ”capsule” in the AP potentially could be confused with rim APHE. See Pitfalls (page 16-57) for how to distinguish

Enhancing "Capsule"

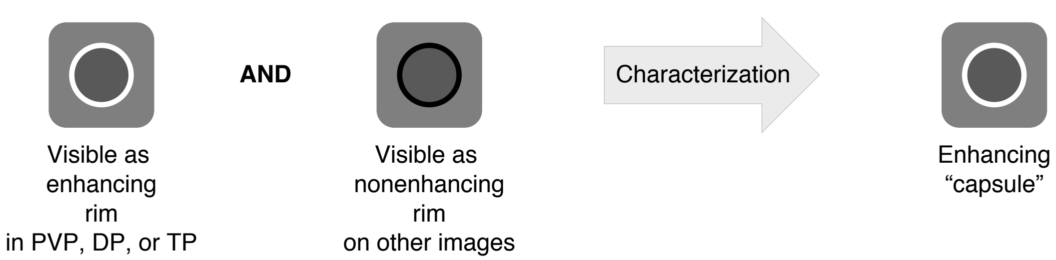
RADLEX ID: N/A

Characterization (Cont'd)

Enhancing "capsule" must be unequivocally thicker or more conspicuous than fibrotic tissue around background nodules.



If a "capsule" is visible as both an enhancing rim on PVP, DP or TP images AND as a nonenhancing rim on other images, characterize as enhancing "capsule", NOT as nonenhancing "capsule".



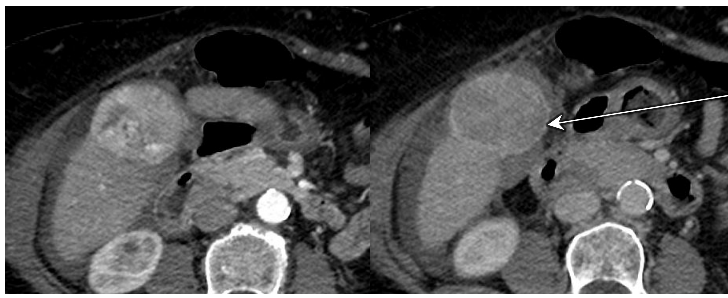
See page 16-309 for more information on nonenhancing "capsule".

Enhancing "Capsule"

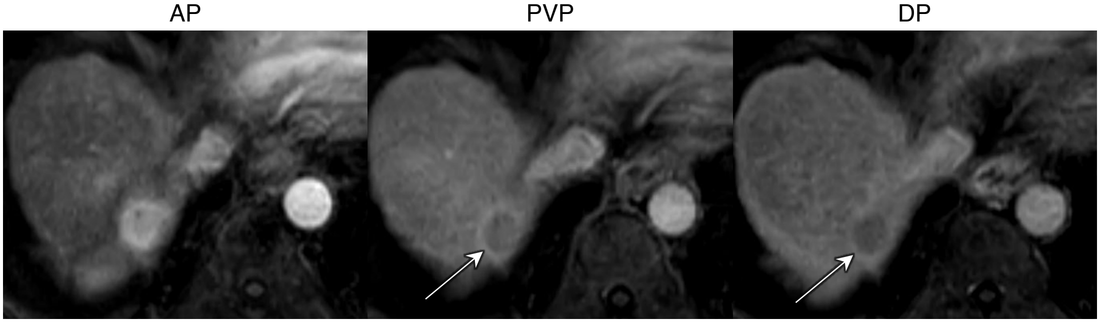
RADLEX ID: N/A

Characterization (Cont'd)

Example: CT



Example: ECA-MRI

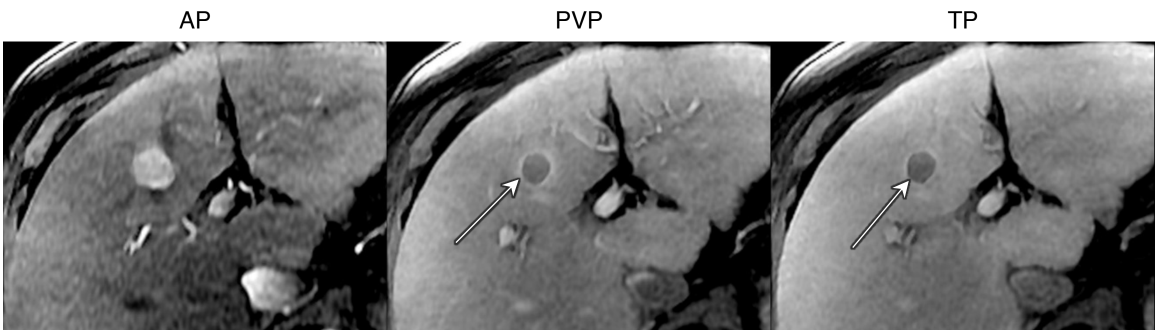


Enhancing “Capsule”

RADLEX ID: N/A

Characterization (Cont'd)

Example: Gx-MRI

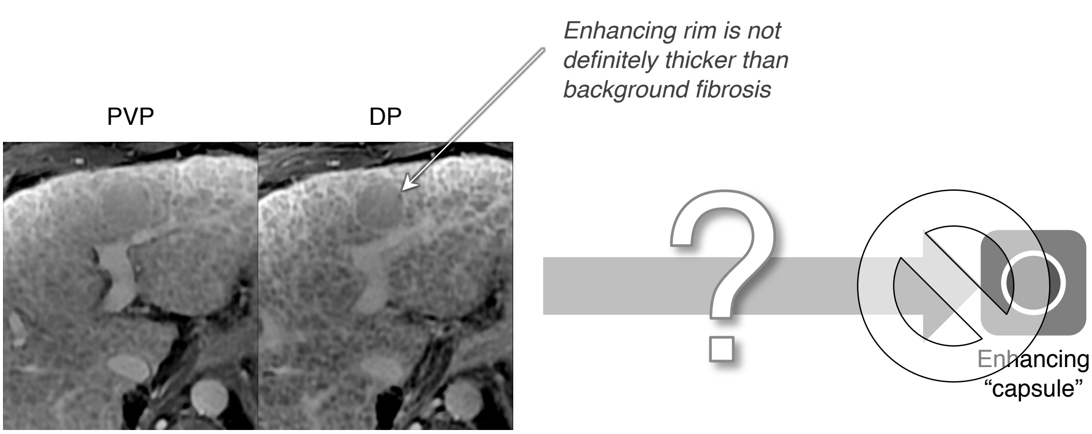


Enhancing “capsule” in PVP   Enhancing “capsule” in TP

If unsure

If unsure that “capsule” is present, do not characterize as “capsule”.

If unsure that “capsule” is enhancing or nonenhancing, characterize as nonenhancing “capsule”.

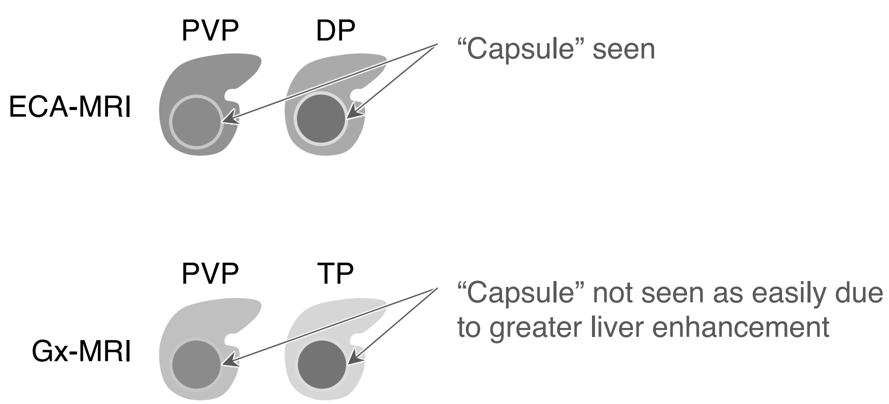


Enhancing “Capsule”

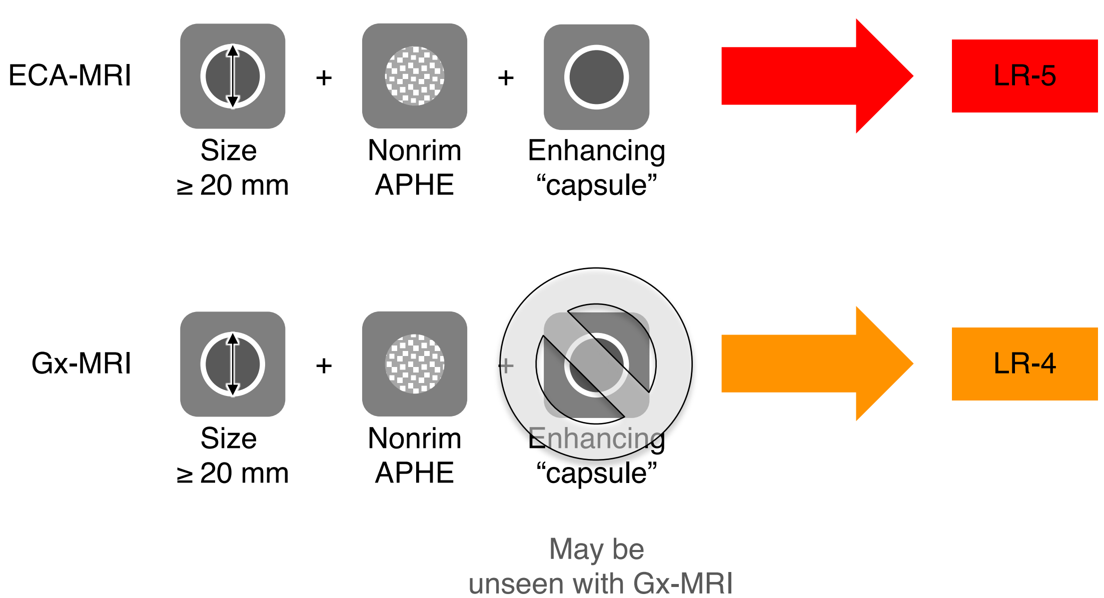
RADLEX ID: N/A

Pitfalls & practical considerations

Enhancing “capsule” may be more difficult to see on gadoxetate-MRI than extracellular agent-MRI. The reason is that the enhancement of the “capsule” may be obscured by the relatively high enhancement of background liver in PVP and TP after gadoxetate injection. Enhancement of background liver in PVP and DP is usually not high enough after ECA injection to obscure the “capsule”



The reduced visibility of enhancing “capsule” can lead to the following discrepancy between ECA-MRI and Gx-MRI:



Consider ECA-MRI if gadoxetate-MRI is equivocal for enhancing “capsule”

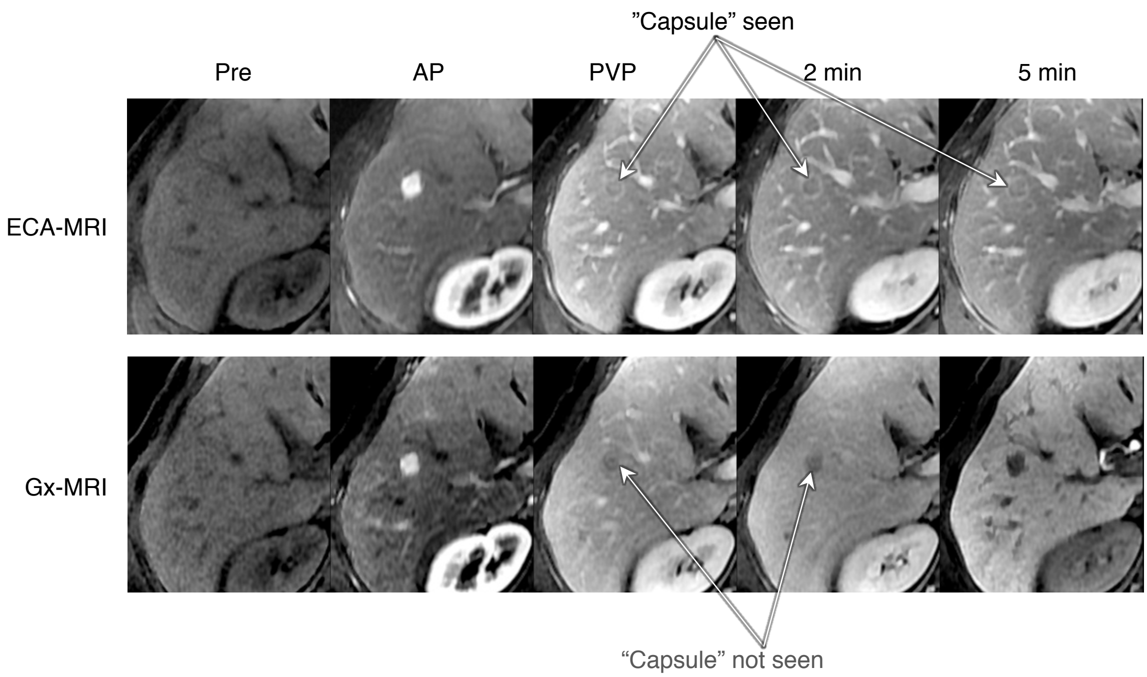
Enhancing "Capsule"

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Example: MRI with ECA vs. MRI with gadoxetate

Enhancing capsule appearance is seen on ECA-MRI, but not on Gx-MRI on exams performed one month apart in same patient



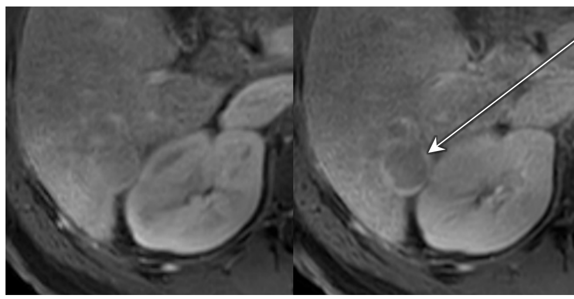
Enhancing “Capsule”

RADLEX ID: N/A

Pitfalls & practical considerations (Cont’d)

Enhancing “capsule” may be more difficult to see in PVP than in delayed phase. Some enhancing “capsules” are seen only in the DP.

PVP DP

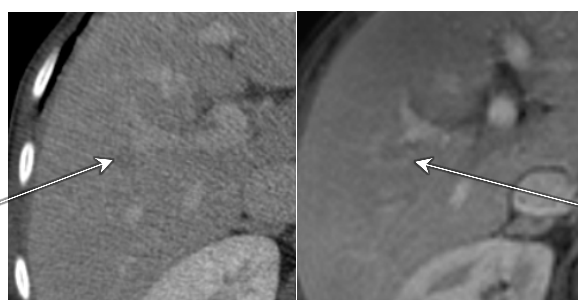


“Capsule” is seen more easily on DP than PVP

Enhancing “capsule” may be difficult to see with CT than MRI due to the lower contrast resolution of CT.

CT MRI

“Capsule” is not seen on CT



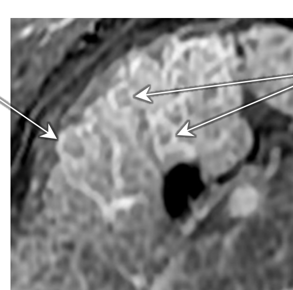
“Capsule” is seen on MRI

Enhancing “capsule” may be difficult to characterize in markedly fibrotic liver.

- Marked fibrosis and parenchymal heterogeneity may obscure “capsule”.
- Marked fibrosis and parenchymal heterogeneity may create false perception of “capsule”.

PVP

Delayed rim of enhancement around observation: is this a “capsule” or just background fibrosis? Since there is uncertainty, characterize as no “capsule” (see page 16-195).



Enhancing fibrous bands around background nodules

Enhancing “Capsule”

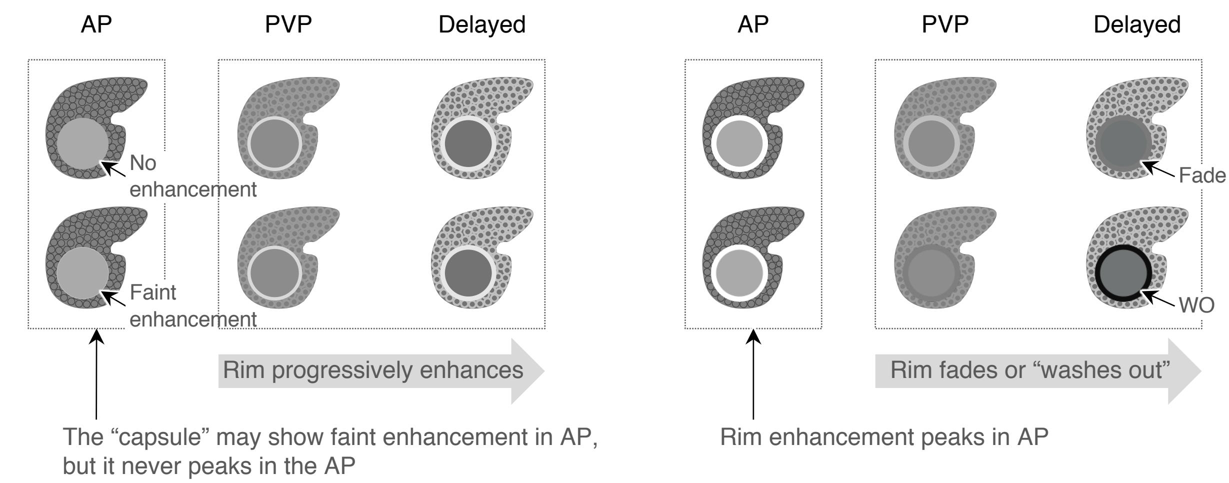
RADLEX ID: N/A

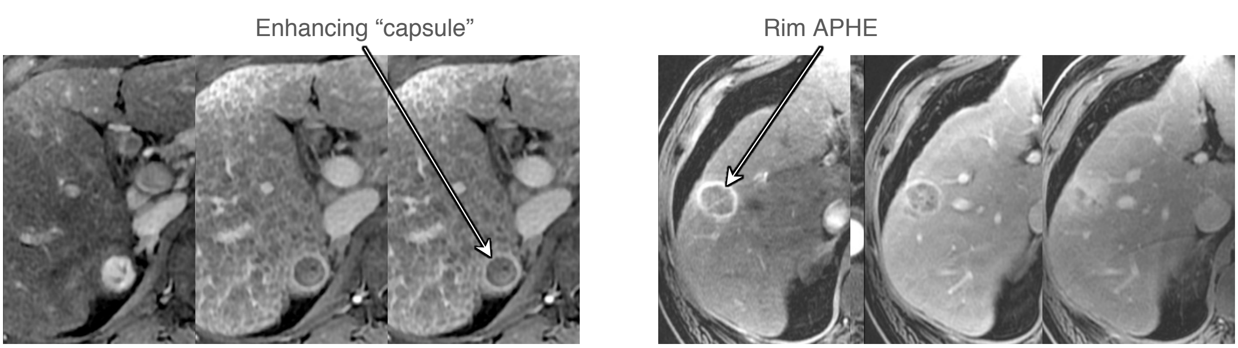
Pitfalls & practical considerations (Cont’d)

Rim APHE (see page 16-57) conceivably could be confused with enhancing “capsule”.

- Like enhancing “capsule”, rim APHE manifests as a rim of enhancement
- Differentiation is possible by looking at the temporal pattern:
  - The “capsule” progressively enhances. The enhancement usually begins *after* the AP and peaks in the PVP, DP, or TP. There can be faint enhancement in AP, but it never peaks in AP.
  - Rim APHE has opposite pattern. It peaks in AP and then fades or “washes out” (peripheral “washout”). It never progressively enhances.

Enhancing “capsule” | Rim APHE





- Enhancing “capsule” and rim APHE also can differ in morphology. Enhancing “capsule” is smooth, sharp, uniform. Rim APHE may be thick, irregular, less sharply defined (see page 16-57).

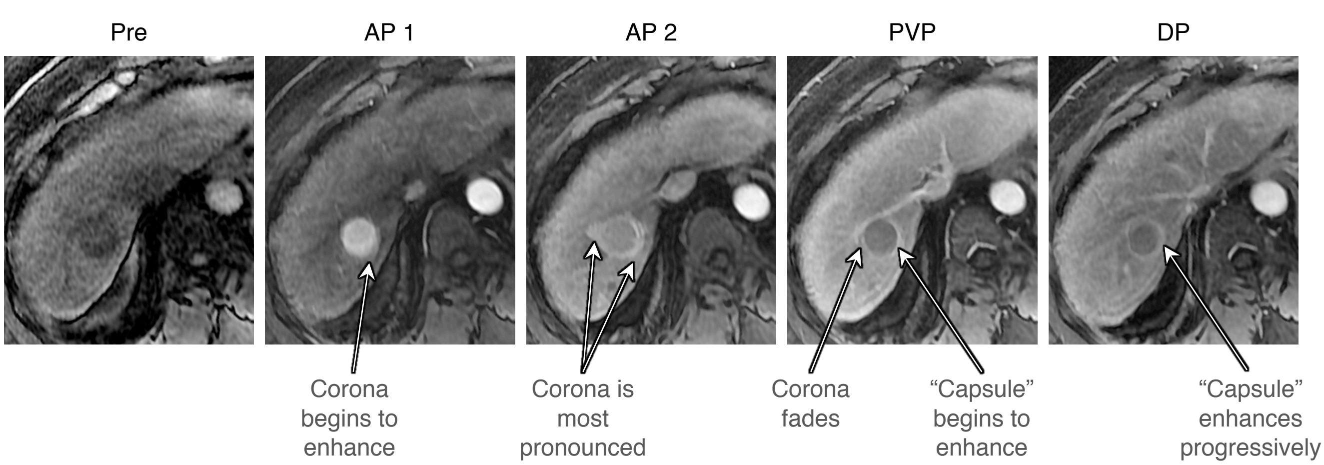
Enhancing "Capsule"

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Corona enhancement (see page 16-265) conceivably could be confused with enhancing "capsule".

- Like enhancing "capsule", corona enhancement manifests as a partly or entirely circumferential zone of enhancement
- Differentiation is possible by looking at the temporal pattern:
    - If rim enhancement increases in PVP, DP, or TP, characterize as enhancing "capsule".
    - If rim enhancement occurs in late arterial phase or early PVP and then fades, characterize as corona enhancement.
- Enhancing "capsule" and corona enhancement also differ in morphology.
    - Enhancing "capsule" is a discrete structure. It is smooth, sharp, and uniform. Enhancing "capsule" forms the edge of the observation.
    - Corona enhancement is a perfusional phenomenon, not a discrete structure. It may be thick, tends to eccentric, is usually less well defined, and extends beyond the edge of the observation into the adjacent parenchyma.
- Corona enhancement and enhancing "capsule" may coexist in the same observation.
    - The corona enhances in the late AP or early PVP then fades. As the corona fades, the "capsule" enhances progressively.



Enhancing “Capsule”

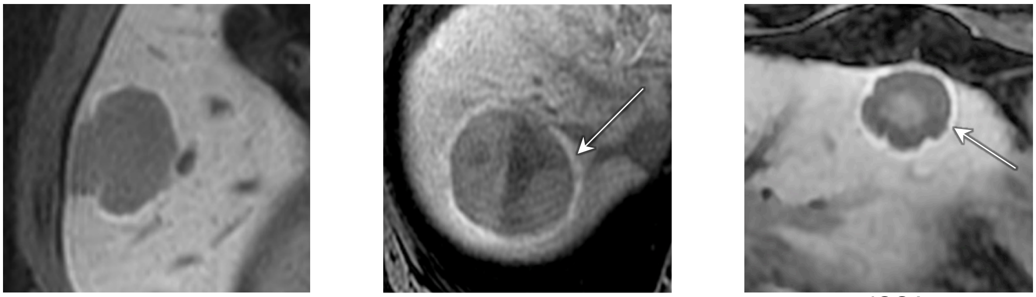
RADLEX ID: N/A

Pitfalls & practical considerations (Cont’d)

HBP hyperintense rim could be be mistaken for enhancing “capsule”.

- A hyperintense rim may be visible around both benign (e.g., FNH, HCA) and malignant (e.g., HCC, metastasis) liver masses in the hepatobiliary phase after administration of gadobenate or gadoxetate. The HBP hyperintense rim indicates the presence of functioning hepatocytes around the lesion, thereby excluding the possibility of a true tumor capsule, which is composed of fibrous tissue and not hepatocytes. Since HBP hyperintense rim occurs with benign and malignant lesions and since it excludes true tumor capsule, this imaging feature should not be characterized as a “capsule”.

HBP HBP HBP



Adenoma HCC iCCA

Other mimics

- Peripheral granulomatous tissue after locoregional treatment may mimic “capsule”.
- Rim-enhancing abscess should be differentiated from “capsule”.

Radiologic “capsule” does not always represent a true tumor capsule.

- A radiologic “capsule” may represent a pseudocapsule comprising perilesional sinusoids, fibrous tissue, and compressed liver parenchyma. The distinction between true tumor capsule and pseudocapsule can only be made at pathology, but this distinction does not appear important for diagnosing HCC or evaluating its biological behavior. In at-risk patients, enhancing “capsule” has high PPV for HCC, regardless of whether it represents true tumor capsule or pseudocapsule.
- Cirrhosis-associated nodules are surrounded by mixed fibrous tissue which may enhance at imaging and be mistaken for a “capsule”. Characterize as “capsule” only if rim enhancement is unequivocally thicker or more conspicuous than the fibrous tissue around background nodules.

Enhancing “Capsule”

RADLEX ID: N/A

Pitfalls & practical considerations (Cont’d)

Multiplanar images may help demonstrate “capsule”.

Assessment of enhancing “capsule” on subtraction images is challenging due to misregistration.

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Enhancing “Capsule”

RADLEX ID: N/A

References (Cont’d)

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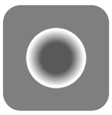
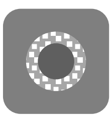
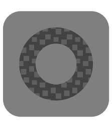
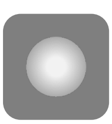
Nonenhancing “Capsule”

RADLEX ID: N/A

See page 16-309 for nonenhancing “capsule”.

Targetoid Appearance and its Manifestations

RADLEX ID:

Feature	Definition	*Page*
"Targetoid" 	Target-like imaging morphology. Concentric arrangement of internal components.	*16-207*
Manifestations of targetoid		
Rim APHE 	Spatially defined subtype of APHE in which arterial phase enhancement is most pronounced in observation periphery	*16-38*
Peripheral "Washout" 	Spatially defined subtype of "washout" in which apparent washout is most pronounced in observation periphery	*16-125*
Delayed central enhancement 	Central area of progressive postarterial phase enhancement	*16-221*
Targetoid restriction 	Concentric pattern on DWI characterized by restricted diffusion in observation periphery with less restricted diffusion in observation center	*16-234*
Targetoid TP or HBP appearance 	Concentric pattern in TP or HBP characterized by moderate-to-marked hypointensity in observation periphery with milder hypointensity in center	*16-227*

Targetoid Manifestations

RADLEX ID: N/A

The below table summarizes the sequences on which various targetoid features are seen

Feature	Early AP	Late AP	PVP	DP	TP	HBP	DWI
Rim APHE	+	++	—	—	—	—	—
Peripheral “washout”	—	—	+	++	—	—	—
Delayed central enhancement	—	—	+	++	—	—	—
Targetoid TP/HBP	—	—	—	—	+	+	—
Targetoid restriction	—	—	—	—	—	—	++

- “+” indicates the phase where the feature may be seen
- “++” indicates the phase where the feature is optimally seen
- Targetoid appearance may occasionally be seen on noncontrast images other than DWI, but it is not currently included as part of targetoid manifestation.
- TP/HBP: single “+” is assigned to each one as the feature is seen equally well on both

Targetoid

RADLEX ID: N/A

Definition

Target-like morphological pattern. Concentric arrangement of internal components with the following manifestations on various phases or sequences:

- Rim APHE *(page 16-38)*
- Peripheral "washout" *(page 16-125)*
- Delayed central enhancement *(page 16-221)*
- Targetoid appearance in transitional and/or hepatobiliary phase *(page 16-227)*
- Targetoid diffusion restriction *(page 16-234)*

Synonyms

Target-like, target appearance

Terminology

LI-RADS uses the term targetoid to describe a family of imaging features characteristic of non-HCC malignancies and atypical of HCC. These features are thought to reflect peripheral arterialization and hypercellularity in conjunction with central fibrosis or ischemia. The term "targetoid" is preferred over "target-like".

Applicable modalities

CT, MRI

Type of feature

Family of LR-M features

Effect on categorization

Any of the targetoid manifestations are sufficient for LR-M categorization.

Exceptions:

- If there is tumor in vein, categorize as LR-TIV.
- If observation is path proven, report path diagnosis, not LI-RADS category.
- If the observation is thought to be an abscess (see page 16-50), categorize as LR-1 or LR-2 depending on confidence level.

Targetoid

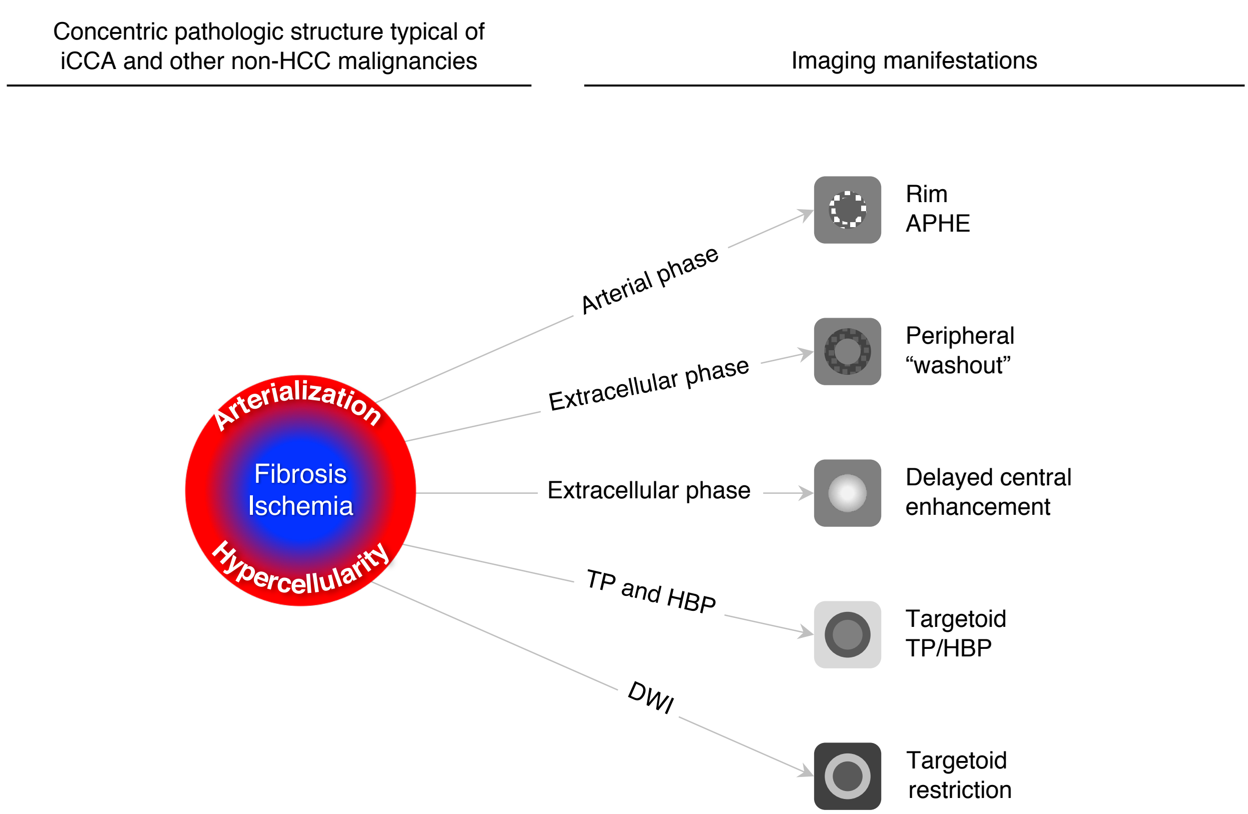
RADLEX ID: N/A

Biological basis

Targetoid appearance is a constellation of LR-M features with similar biological basis and often co-existing in the same observation. This constellation includes rim APHE, peripheral "washout", delayed central enhancement, targetoid restriction, and targetoid appearance in TP and/or HBP images.

Targetoid imaging appearance is thought to reflect the concentric pathologic structure typical of iCCA and other non-HCC malignancies:

- cellular and vascular elements concentrated in the periphery **AND**
- stromal fibrosis or ischemia in the center.



By comparison, most HCCs do not have a concentric structure at pathology.

- HCCs tend to have a uniform, nodule-in-nodule, or mosaic structure.

Therefore, a concentric structure at imaging favors non-HCC malignancy.

Some HCCs do have a concentric structure, however, and have a targetoid appearance. See Pitfalls (*page 16-212*).

Targetoid

RADLEX ID: N/A

Summary of evidence

Emerging evidence indicates that targetoid appearance on dynamic imaging, DWI, or HBP is

- characteristic of iCCA, cHCC-CCA or other non-HCC malignancies **AND**
- uncharacteristic of HCC

Below is the reported frequency of each targetoid feature for HCC, iCCA, and cHCC-CCA in at-risk patients

	Rim APHE	Peripehral "washout"	Delayed central enhancement	Targetoid TP/HBP	Targetoid diffusion restriction
HCC†	0-25%	1-4%	0-15%	2-36%	0-15%
iCCA	37-94%	12-31%	59-100%	42-100%	26-75%
cHCC-CCA	42-59%	10-16%	33-74%	37-55%	10%

† Scirrhous HCCs have higher incidence of targetoid features: rim APHE 60-80%, delayed central enhancement 80%, targetoid on DWI 83%, targetoid on TP/HBP 0-78%

Targetoid

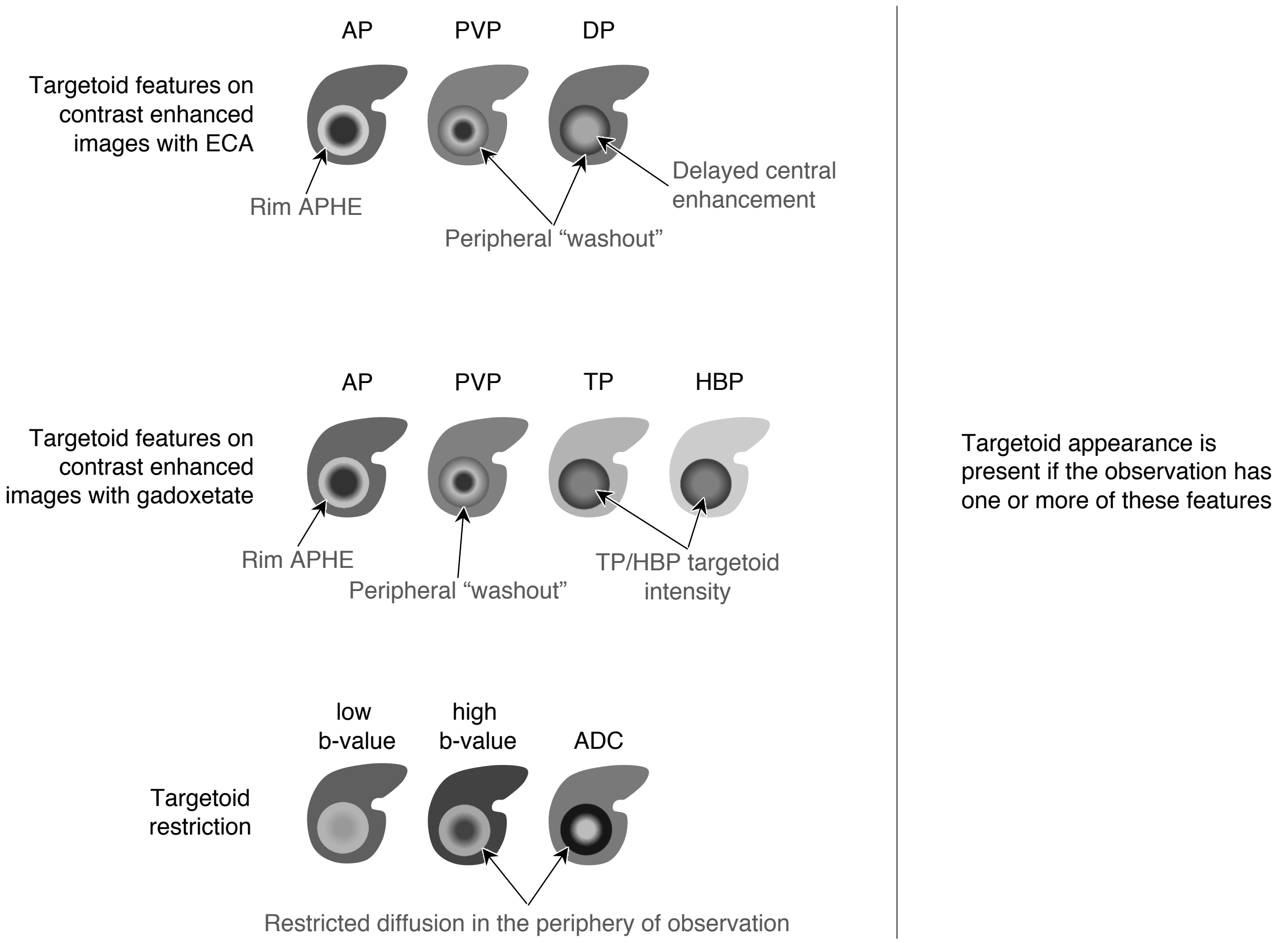
RADLEX ID: N/A

Characterization

Characterize targetoid appearance on contrast-enhanced CT, contrast-enhanced MRI, diffusion-weighted imaging.

Targetoid appearance is present if the observation has **ONE OR MORE** of the following features:

- Rim APHE (*page 16-38*) **OR**
- Peripheral “washout” (*page 16-125*) **OR**
- Delayed central enhancement (*page 16-221*) **OR**
- Targetoid appearance on TP or HBP (*page 16-227*) **OR**
- Targetoid diffusion restriction (*page 16-234*)



Targetoid

RADLEX ID: N/A

If unsure

If unsure whether an observation has a targetoid appearance, characterize as targetoid.

Rationale: this prompts LR-M categorization and alerts referrer to possibility of non-HCC malignancy

Targetoid

RADLEX ID: N/A

Pitfalls & practical considerations

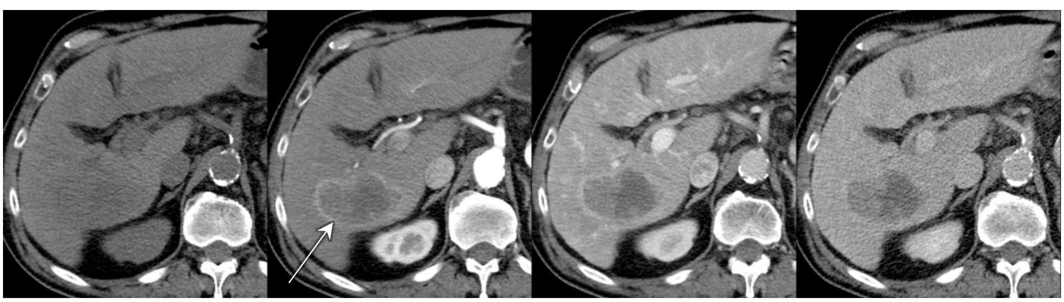
Some HCCs may have a targetoid appearance: namely, HCCs with central

- steatosis (e.g., steatohepatitic HCC)
- blood products (e.g., hemorrhagic HCC)
- fibrosis (e.g., scirrhous HCC)
- necrosis (e.g., poorly differentiated HCC)

Thus, while targetoid appearance suggests non-HCC malignancy and prompts LR-M categorization, it does not exclude HCC.

Example: CT – Path-proven HCC with targetoid appearance

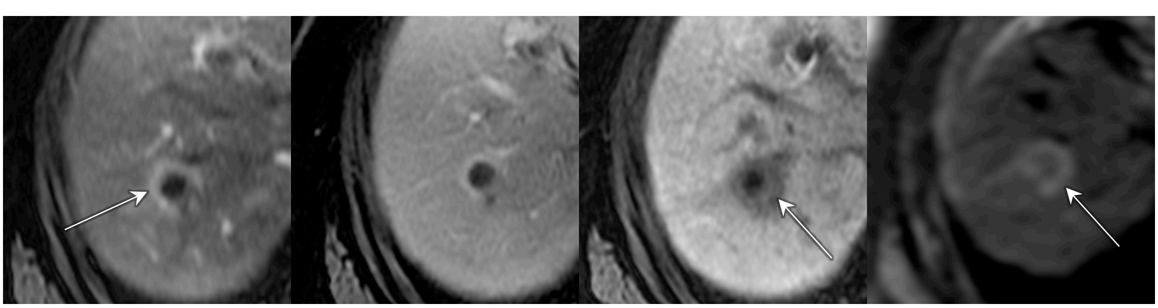
AP PVP DP



Rim APHE

Example: Gx-MRI – Path-proven HCC with targetoid appearance

AP PVP HBP DWI B=600



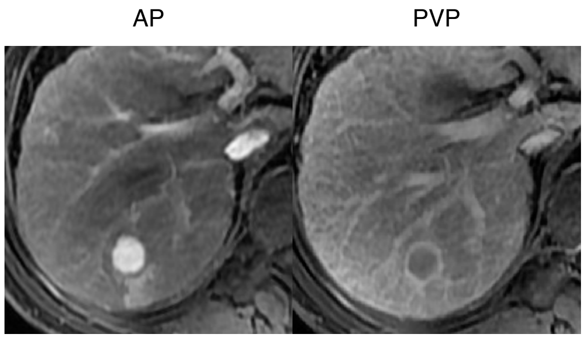
Rim APHE Targetoid HBP Targetoid diffusion

Targetoid

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Small iCCAs and other non-HCC malignancies may have a uniform appearance rather than a targetoid appearance. For example, they may have nonrim APHE and nonperipheral "washout". Such tumors occasionally may be miscategorized as LR-5.

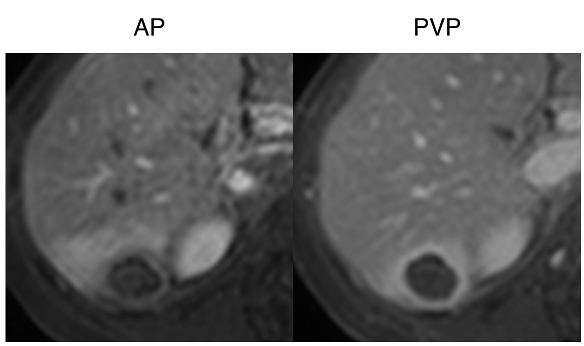


Pathologically-proven iCCA with nonrim APHE and nonperipheral WO
Note presence of enhancing "capsule" as well

Observation was categized as LR-5 and surgically resected
Pathology diagnosis = iCCA

Some inflammatory lesions (e.g., abscess) may have targetoid appearance.

These typically have thin enhancing walls and septations but no solid components, and they show no delayed central enhancement. Thus, presence of solid components in a targetoid mass excludes abscess.



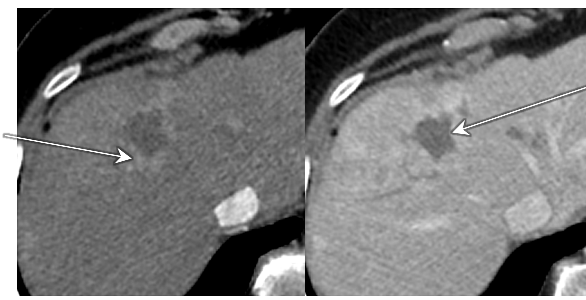
Rarely, a necrotic tumor may have a thin arterialized rim without visible solid components or delayed central enhancement. In such cases, imaging-based differentiation from abscess may be difficult.

Targetoid

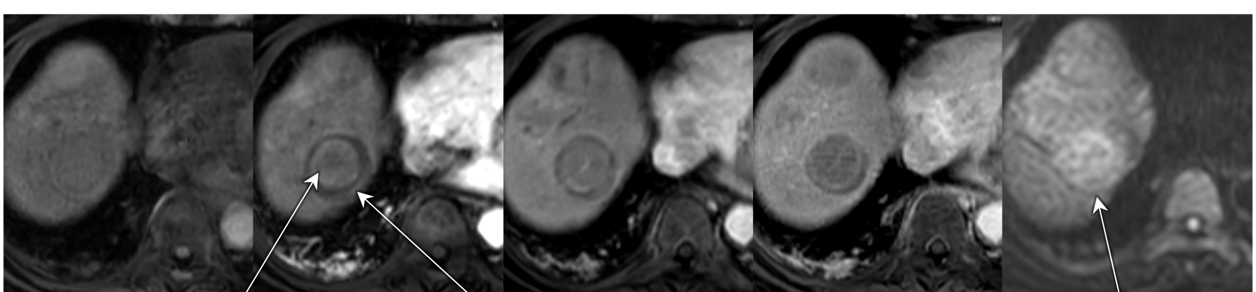
RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Treated lesions may have a postprocedure rim of enhancing granulation tissue that may resemble targetoid appearance. Thus, do not apply targetoid appearance to treated lesions.



Rarely, a centrally located inner nodule within a larger nodule (nodule-in-nodule) may have a concentric appearance and be mistaken for a targetoid mass. Thus, apply targetoid appearance only to masses where the targetoid appearance is the result of hypercellular/hypervascular periphery and more fibrous center. See page 16-208.



Targetoid

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Corona enhancement (see page 16-265) may resemble rim APHE. Unlike rim APHE, corona enhancement occurs in the periobservation parenchyma, not the lesion itself.

Enhancing capsule (see page 16-187) and nonenhancing "capsule" (see page 16-309) are concentric imaging features that conceivably could be confused with targetoid appearance.

- The thinness, uniformity, and sharpness of the "capsule" permits reliable differentiation from targetoid appearance, which typically is not as thin and may be irregular.
- Additionally, the temporal enhancement pattern of enhancing "capsule" (enhances progressively) is the opposite of targetoid enhancement (rim enhances in arterial phase and then fades or appears to wash out on post-arterial phases)(see page 16-57).

For more information on pitfalls:

- rim APHE *(page 16-38)*
- peripheral "washout" *(page 16-125)*
- delayed central enhancement *(page 16-221)*
- targetoid TP/HBP appearance *(page 16-231)*
- targetoid restriction *(page 16-238)*

Targetoid

RADLEX ID: N/A

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Targetoid

RADLEX ID: N/A

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Targetoid

RADLEX ID: N/A

References (Cont'd)

Park HJ, Kim YK, Park MJ, Lee WJ. Small intrahepatic mass-forming cholangiocarcinoma: target sign on diffusion-weighted imaging for differentiation from hepatocellular carcinoma. Abdom Imaging. 2013; 38(4):793-801.

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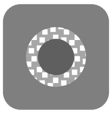
Wells ML, Venkatesh SK, Chandan VS, et al. Biphenotypic hepatic tumors: imaging findings and review of literature. Abdominal Imaging. 2015;40(7):2293-305.



Rim APHE

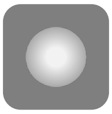
RADLEX ID: N/A

See *page 16-38*.

Peripheral "Washout"

RADLEX ID: RID49817

See *page 16-125*.



Delayed Central Enhancement

RADLEX ID: N/A

Definition

Central area of progressive postarterial phase enhancement.

Synonyms

Sustained central enhancement, concentric progressive enhancement, centripetal progressive enhancement

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Terminology

The term delayed central enhancement is preferred as it is commonly used in the literature. Additionally, this terminology does not overlap with that used to describe benign entities (such as hemangiomas) which might display progressive enhancement.

The adjective “delayed” refers to the postarterial extracellular phases, and not to the delayed phase in particular.

The adjective “central” refers to **inner** portions of the observation but is not meant to imply that the delayed enhancement is literally in the geometric center of the observation.

Applicable modalities

CT, MRI

Since “delayed” refers to the postarterial extracellular phases, and not to the the delayed phase in particular, this feature can be assessed with any type of contrast agent:

- Using ECP or gadobenate: PVP or DP
- Using gadoxetate: PVP

Type of feature

Targetoid LR-M feature

Delayed Central Enhancement

RADLEX ID: N/A

Effect on categorization

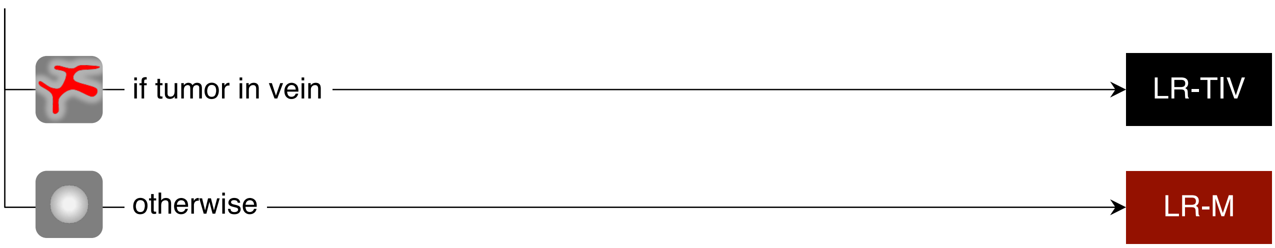
Delayed central enhancement is sufficient for LR-M. See page 16-9.

By itself, it is enough for LR-M.

Thus, all untreated observations with delayed central enhancement are LR-M, regardless of other imaging features.

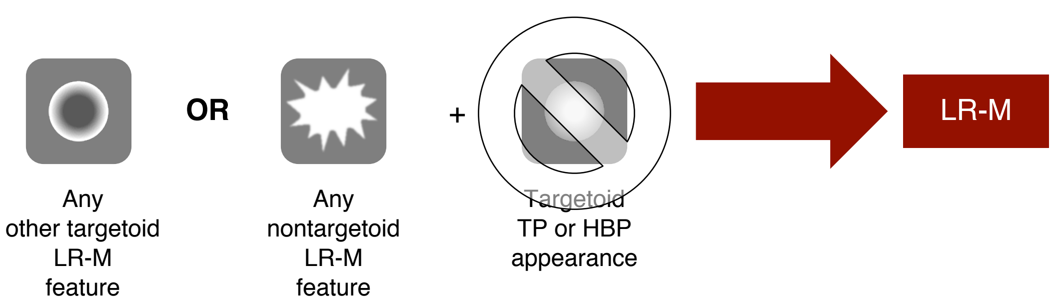
- Exceptions:
  - If there is tumor in vein, categorize as LR-TIV.
  - If observation is path proven, report path diagnosis, not LI-RADS category.

Nonpath-proven observation with rim APHE



Delayed central enhancement is not required for LR-M

Observations without delayed central enhancement can be LR-M if other LR-M features are present.



Delayed Central Enhancement

RADLEX ID: N/A

Biological basis

After injection into the circulation, small molecules (such as low molecular weight contrast agents) progressively accumulate in the fibrotic or ischemic portions of tumors. The reasons are that:

- Fibrosis has large extracellular spaces. It acts like a “sponge” that retains administered contrast material.
- Ischemia is associated with sluggish blood flow. Once it enters the ischemic areas, administered contrast material is slow to leave.

Cholangiocarcinomas and other non-HCC malignancies tend to be ischemic and/or fibrotic in their centers. Therefore, the central tumor stroma enhances in a progressive/delayed pattern following injection of contrast agents.

By comparison, the arterialized, hypercellular tumor periphery has a relatively small extracellular compartment, is characterized by brisk blood flow, and does not trap the agent.

Summary of evidence

Single-center, retrospective studies of patients both with and without underlying risk factors for chronic liver disease have described this enhancement pattern as a component of targetoid dynamic enhancement associated with non-HCC malignancies.

- Delayed central enhancement has been reported in
  - 59-100% of iCCA
  - 33-74% of cHCC-CCA
  - 0-15% of path-proven HCCs
  - 80% of path-proven scirrhous HCC

Note that delayed central enhancement does not exclude HCC (see Pitfalls, page 16-226).

Delayed central enhancement occurs in association with other targetoid LR-M features since it is thought to reflect the same underlying pathology (see page 16-208).

The frequency and diagnostic accuracy of delayed central enhancement in the absence of other targetoid LR-M features is unknown.

Delayed Central Enhancement

RADLEX ID: N/A

Characterization

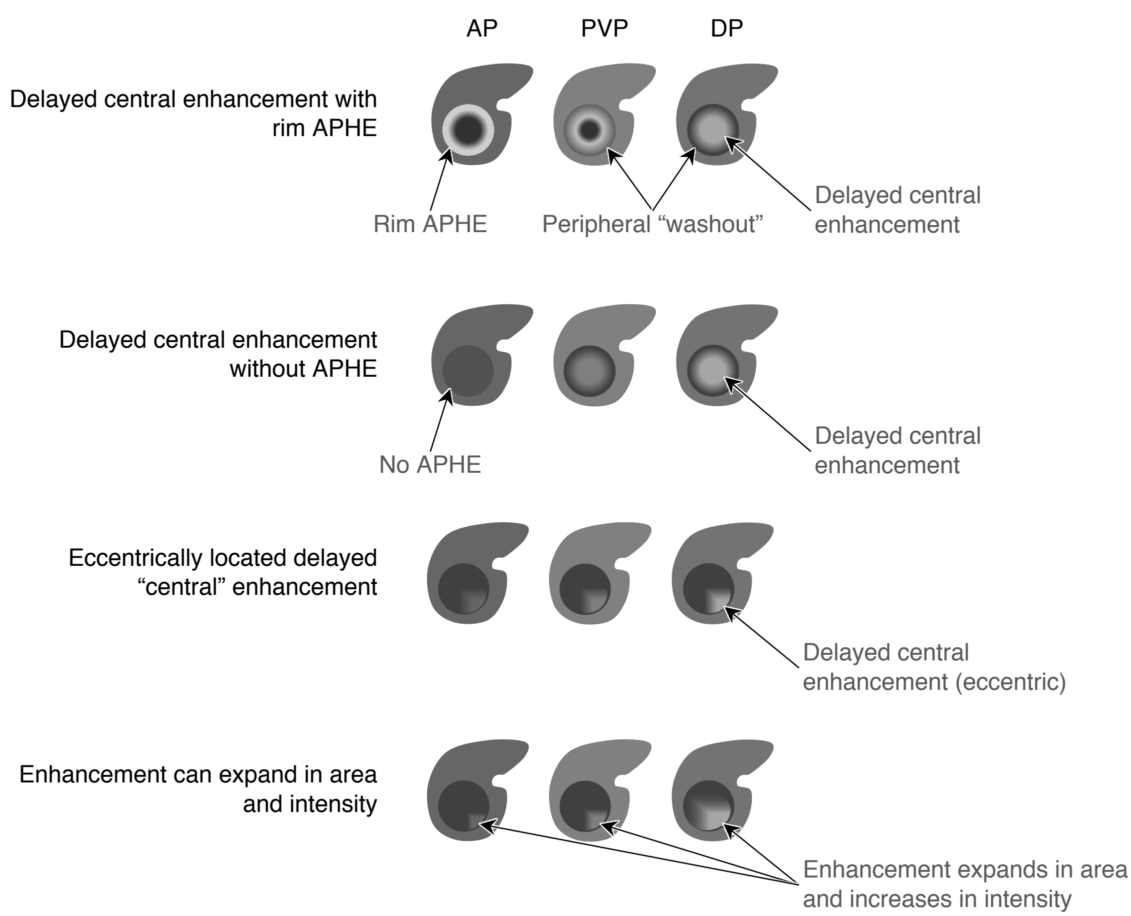
Characterize on dynamic contrast-enhanced images, comparing postarterial extracellular phase images with arterial phase images.

Delayed central enhancement is present if on dynamic imaging there is progressive increase in signal intensity/attenuation relative to liver within inner portions of an observation due to accumulation of contrast material.

Both the degree and the area of enhancement may increase on successively more delayed phases.

Delayed central enhancement frequently occurs in conjunction with rim APHE but the presence of rim APHE is not necessary. Some observations without any type of APHE have delayed central enhancement.

The delayed central enhancement must involve inner portions of the observation but may be eccentrically located (i.e., it may not be in the geometric center of the observation).

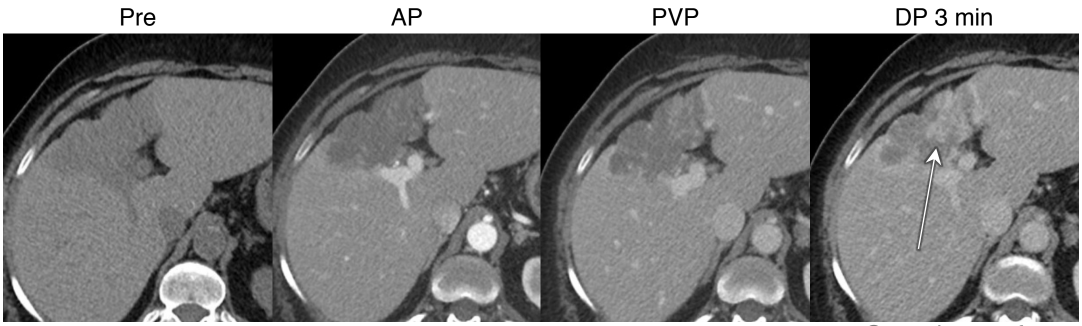


Delayed Central Enhancement

RADLEX ID: N/A

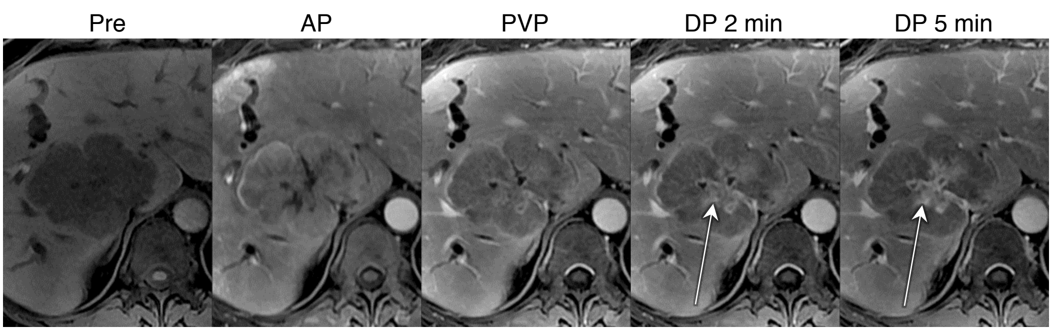
Characterization (Cont'd)

Example: CT



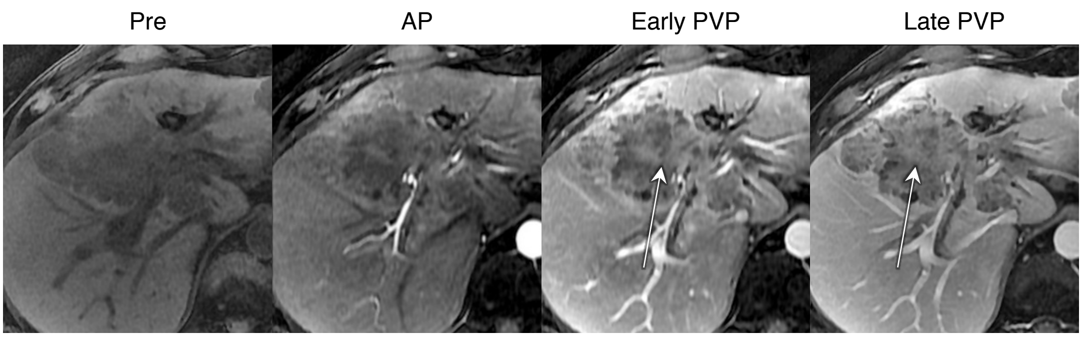
Central area of enhancement (eccentric)

Example: ECA-MRI



Central area of enhancement

Example: Gx-MRI



Central area of enhancement

Delayed Central Enhancement

RADLEX ID: N/A

If unsure

If unsure between delayed central enhancement and no delayed central enhancement, characterize as delayed central enhancement.

Pitfalls & practical considerations

May be difficult to characterize on gadoxetate-enhanced MRI due to dynamic uptake of contrast within the liver and diminished enhancement of blood pool following the portal venous phase.

Benign lesions like hemangiomas may accumulate contrast and should be excluded by evaluating other features (e.g. marked T2 weighted hyperintensity, peripheral nodular enhancement pattern, enhancement paralleling blood pool on all postcontrast phases).

Abscesses have a concentric structure and may manifest rim APHE and/or targetoid diffusion restriction. However, abscesses do not show delayed central enhancement since the purulent material in the abscess cavity is avascular and does not enhance. Thus, unlike some targetoid features (rim APHE, targetoid restriction), delayed central enhancement excludes abscess from consideration.

References

Fowler KJ, Sheybani A, Parker RA, 3rd, et al. Combined hepatocellular and cholangiocarcinoma (biphenotypic) tumors: imaging features and diagnostic accuracy of contrast-enhanced CT and MRI. AJR. 2013;201(2):332-9.

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Jeong HT, Kim MJ, Chung YE, Choi JY, et al. Gadoxetate disodium-enhanced MRI of mass-forming intrahepatic cholangiocarcinoma: imaging-histologic correlation. AJR. 2013;201(4):W603-11.

Kovac JD, Galun D, Duric-Stefanovic A, et al. Intrahepatic mass-forming cholangiocarcinoma and solitary hypovascular liver metastases: is the differential diagnosis using diffusion-weighted MRI possible? Acta Radiol. 58(12):1417-1426.

Mamone G, Marrone G, Caruso S, et al. Intrahepatic mass-forming cholangiocarcinoma: enhancement pattern on Gd-BOPTA-MRI with emphasis on hepatobiliary phase. Abdom Imaging. 2015; 40(7):2313-22.

Nishie A, Yoshimitsu K, Asayama Y, et al. Detection of combined hepatocellular and cholangiocarcinomas on enhanced CT: comparison with histologic findings. AJR. 2005;184(4):1157-62.

Targetoid TP or HBP appearance

RADLEX ID: N/A

Definition

Concentric pattern in TP or HBP characterized by moderate-to-marked hypointensity in observation periphery with lesser degree of central hypointensity compared to background liver.

Synonyms

HBP/TP cloud, HBP/TP target sign/appearance

Terminology

The term “targetoid TP or HBP appearance” is preferred as it is consistent with the terminology used by LI-RADS for the entire family of targetoid LR-M features.

Applicable modalities

MRI with gadoxetate

Type of feature

Targetoid LR-M feature

Targetoid TP or HBP appearance

RADLEX ID: N/A

Effect on categorization

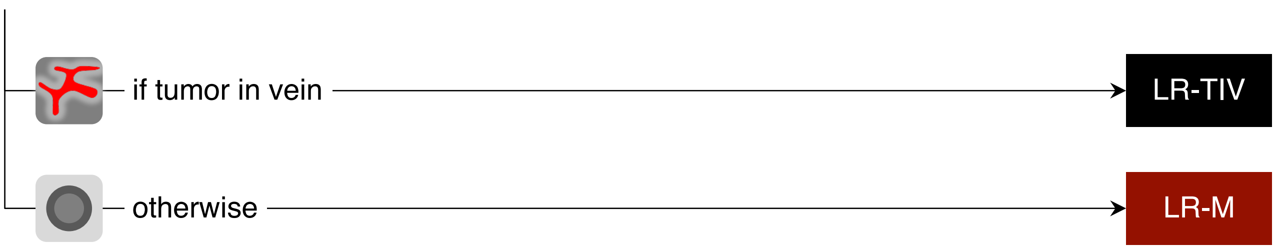
Targetoid TP or HBP appearance is sufficient for LR-M categorization. See *page 16-9*.

By itself, it is enough for LR-M.

Thus, all untreated observations with TP or HBP appearance are LR-M, regardless of other imaging features.

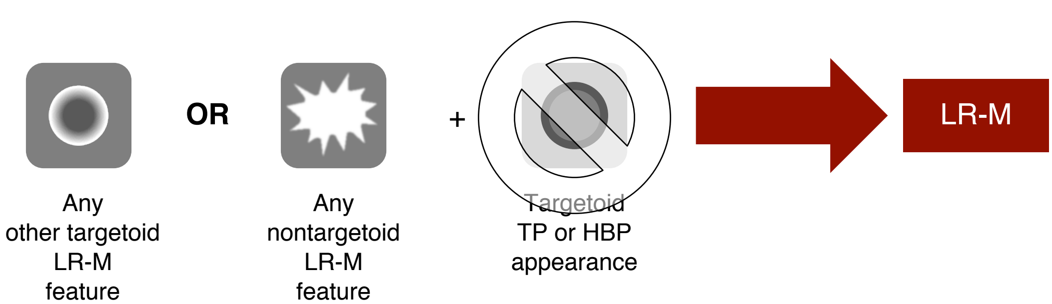
- Exceptions:
  - If there is tumor in vein, categorize as LR-TIV.
  - If observation is path proven, report path diagnosis, not LI-RADS category.

Nonpath-proven observation with targetoid or HBP appearance



Targetoid TP or HBP appearance is not required for LR-M

Observations without targetoid TP or HBP appearance can be LR-M if other LR-M features are present.



Targetoid TP or HBP appearance

RADLEX ID: N/A

Biological basis

The biological basis is similar to that of delayed central enhancement using extracellular agents and gadobenate disodium (see page 16-223). Cholangiocarcinomas and other non-HCC malignancies tend to be ischemic and/or fibrotic in their centers. Ischemic tissue (slow inflow, slow outflow) and fibrous tissue (enlarged, watery extracellular spaces) gradually accumulate low-molecular-weight contrast agents over the first several minutes after their intravenous injection. As a result, the ischemic and/or fibrotic inner portions of these malignant neoplasms progressively enhance. By comparison, the arterialized, hypercellular tumor periphery has a relatively small extracellular compartment, is characterized by brisk blood flow, and does not trap low molecular weight agents.

For extracellular agents and gadobenate disodium, the progressive enhancement may be intense; with only one main elimination pathway (renal), clearance from the extracellular space is slow and the agents have a prolonged dwell time in the tumor stroma.

For gadoxetate disodium, the enhancement of the central stroma tends to be less intense; the dual elimination pathways (renal and hepatobiliary) accelerates clearance of the agent from the extracellular space and reduces its dwell time and concentration in the tumor stroma.

Summary of evidence

In single-center, retrospective, case-control studies in patients with or without chronic liver disease:

- Targetoid appearance on TP was reported in
  - 86% of iCCA
  - 17% of path-proven HCCs without APHE (“hypovascular” HCCs)
    - No data is available on path-proven HCCs with APHE (“hypervascular” HCCs)

- Targetoid appearance on HBP was reported in
  - 42-100% of iCCA
  - 37-55% of cHCC-CCA
  - 62-77% of mets
  - 2-36% of path-proven HCC
  - 0-78% of path-proven scirrhous HCCs

Targetoid TP or HBP appearance occurs in association with other targetoid LR-M features since it is thought to reflect the same underlying pathology (see page 16-208).

The frequency and diagnostic accuracy of targetoid TP or HBP appearance in the absence of other targetoid LR-M features is not well known.

Targetoid TP or HBP appearance

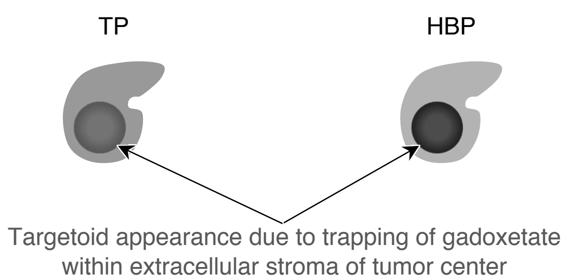
RADLEX ID: N/A

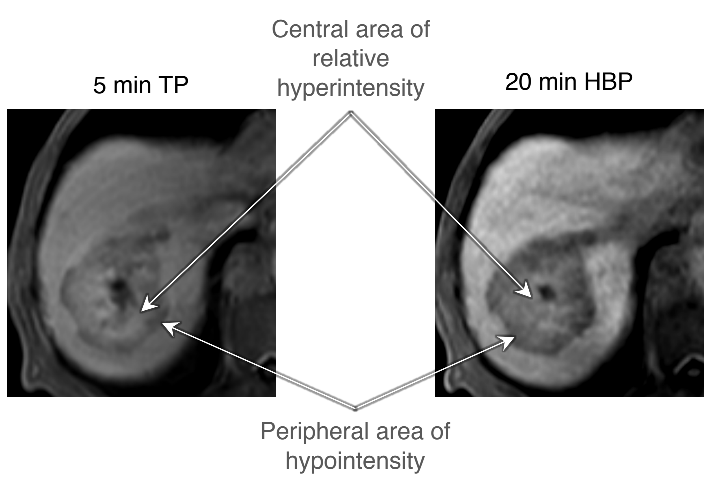
Characterization

Characterize on TP and/or HBP

Targetoid TP or HBP appearance is present if the center of the observation is mildly hyperintense with respect to a peripheral rim of decreased signal intensity.

Targetoid TP or HBP appearance enhancement frequently occurs in conjunction with rim APHE but rim APHE is not necessary. Observations without APHE can have targetoid TP or HBP appearance.





Targetoid TP or HBP appearance

RADLEX ID: N/A

If unsure

If unsure whether there is targetoid TP/HBP appearance, characterize this feature as absent.

Pitfalls & practical considerations

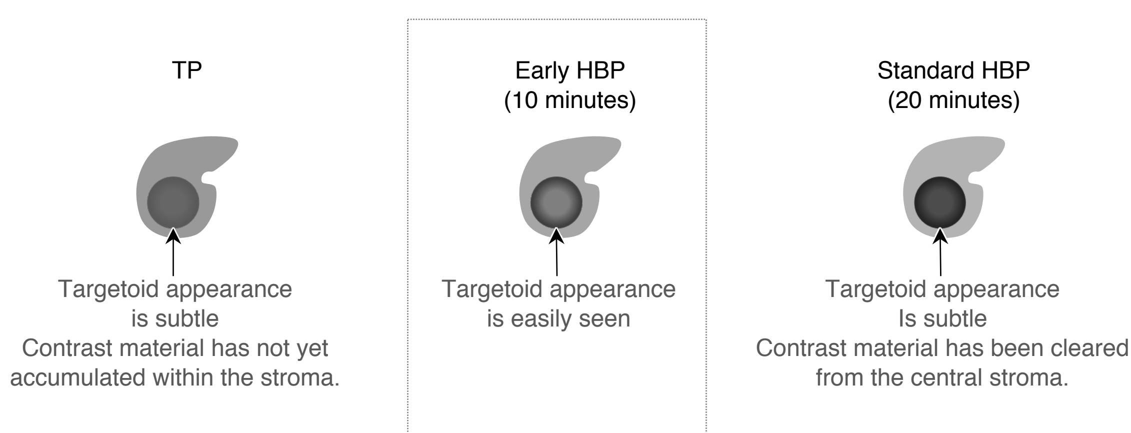
Targetoid appearance on HBP should be differentiated from nonenhancing “capsule”, which is an ancillary feature of malignancy, favoring HCC specifically (see *page 16-309*).

Suboptimal HBP (see *page 13-9*) may make assessment of this feature difficult.

Studies have suggested that targetoid appearance may be characterized more reliably on “early” HBP (~ 10 minutes) images than on transitional (~2-5 minutes) or “standard” HBP (~20 minutes) images.

- Plausible but unproven explanation:
  - 10 minutes provides enough time for the agent to diffuse through the interstitium of the tumor center before being cleared from the extracellular compartment.
  - By comparison,
    - 2-5 minutes may not be enough time for the the agent to diffuse into the tumor interstitium.
    - 20 minutes may be so much time that the agent has been cleared from the extracellular compartment by the dual renal and hepatobiliary elimination pathways.

LI-RADS does not recommend routine acquisition of 10-minute HBP images. Acquisition of such images is optional.



If obtained
(these types of images are **not** required by LI-RADS)

TP and HBP Targetoid Appearance

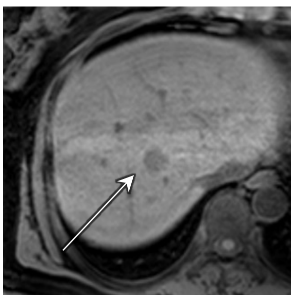
RADLEX ID: N/A

Pitfalls & practical considerations

Small iCCA (< 3 cm) may not have targetoid appearance in the TP or HBP, instead having diffuse hypointensity, complicating their differentiation from HCC.

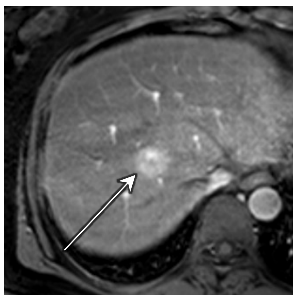
Example: path-proven iCCA with nonrim APHE, nonperipheral WO, and diffuse hypointensity in the TP and HBP (73-yo man with chronic HBV)

Pre



Diffuse APHE
NOT rim APHE

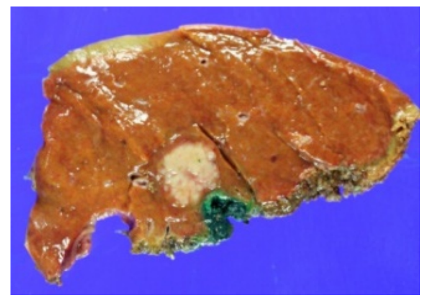
AP



Diffuse APHE
NOT rim APHE

Resection

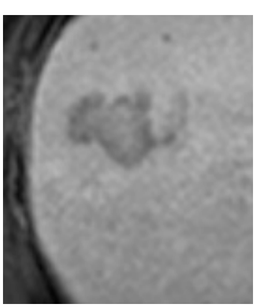
iCCA



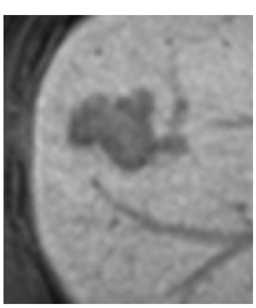
Some HCCs, especially those with fibrous stromas (e.g., scirrhous HCC) may have a targetoid appearance in the TP or HBP

Example: path-proven scirrhous HCC with targetoid appearance in TP and HBP (61-yo man with chronic HBV)

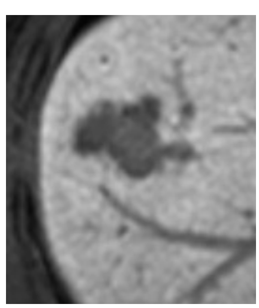
3 min TP



10 min HBP

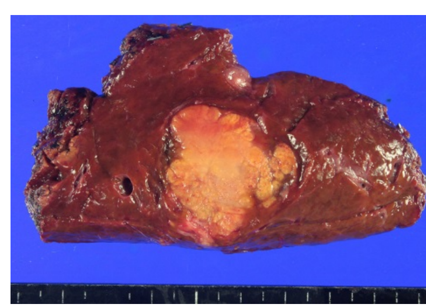


20 min HBP



Resection

Scirrhous HCC



TP and HBP Targetoid Appearance

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Abscesses have a concentric structure and may manifest rim APHE and/or targetoid diffusion restriction. However, abscesses do not show TP and HBP targetoid appearance since the purulent material in the abscess cavity is avascular and does not gradually accumulate contrast material. Thus, unlike some targetoid features (rim APHE, targetoid restriction), TP and HBP targetoid appearance excludes abscess from consideration.

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Haradome H, Unno T, Morisaka H, Toda Y, Kwee TC, Kondo H, Sano K, Ichikawa T, Kondo F, Sugitani M, Takayama T. Gadoxetic acid disodium-enhanced MR imaging of cholangiocellular carcinoma of the liver: imaging characteristics and histopathologic correlations. Eur Radiol. 2017 Nov;27(11):4461-4471.

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Mamone G, Marrone G, Caruso S, Carollo V, Gentile G, Crino' F, Milazzo M, Luca A. Intrahepatic mass-forming cholangiocarcinoma: enhancement pattern on Gd-BOPTA-MRI with emphasis of hepatobiliary phase. Abdom Imaging. 2015 Oct;40(7):2313-22.

Park HJ, Kim YK, Park MJ, Lee WJ. Small intrahepatic mass-forming cholangiocarcinoma: target sign on diffusion-weighted imaging for differentiation from hepatocellular carcinoma. Abdom Imaging. 2013; 38(4):793-801.

Targetoid Restriction

RADLEX ID: N/A

Definition

Concentric pattern on DWI characterized by restricted diffusion in observation periphery with relatively less restricted diffusion in observation center

Synonyms

Peripheral restriction, DWI target sign/appearance, targetoid diffusion

Terminology

The term "targetoid restriction" is preferred as it is consistent with the terminology used by LI-RADS for the entire family of targetoid LR-M features.

Applicable modalities

MRI with diffusion weighted imaging

Type of feature

Targetoid LR-M feature

Targetoid Restriction

RADLEX ID: N/A

Effect on categorization

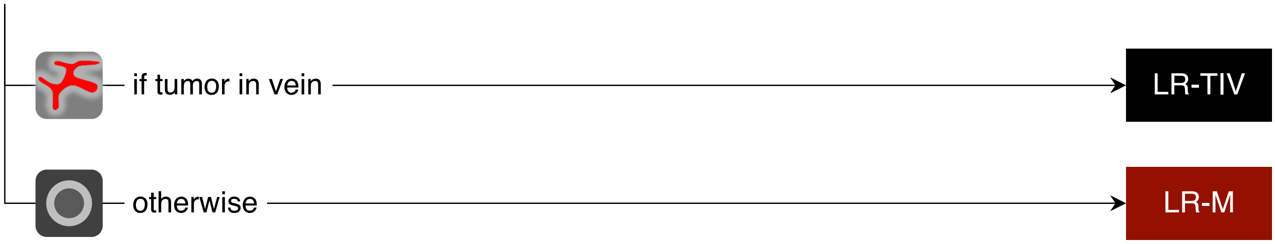
Targetoid restriction is sufficient for LR-M categorization. See page 16-9.

By itself, it is enough for LR-M.

Thus, all untreated observations with targetoid restriction are LR-M, regardless of other imaging features.

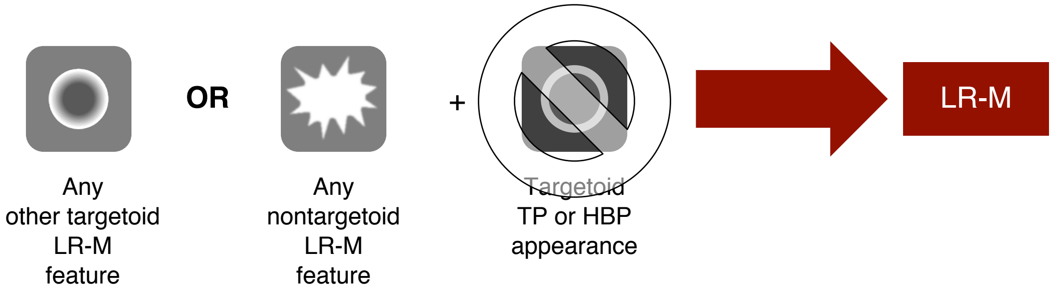
- Exceptions:
    - If there is tumor in vein, categorize as LR-TIV.
    - If observation is path proven, report path diagnosis, not LI-RADS category.

Nonpath-proven observation with targetoid restriction



Targetoid restriction is not required for LR-M

Observations without targetoid restriction can be LR-M if other LR-M features are present.



Targetoid Restriction

RADLEX ID: N/A

Biological basis

Cholangiocarcinomas and other adenocarcinomas are characterized by peripheral hypercellularity and central fibrous stroma and/or ischemia.

The highly cellular areas in the periphery tend to have greater restricted diffusion than the central relatively acellular components, leading to a rim of bright signal intensity on DWI with a corresponding rim of dark signal on ADC maps (i.e., relatively restricted diffusion in the periphery).

Summary of evidence

In single-center, retrospective, case-control studies in patients with or without chronic liver disease:

- Targetoid restriction has been reported in
    - 75% of iCCA
    - 3% of path-proven HCCs
    - 10% of cHCC-CCA
    - (no data on mets)
- Targetoid restriction DWI is an independent predictor of iCCA

Targetoid restriction occurs in association with other targetoid LR-M features since it is thought to reflect the same underlying pathology (see page 16-208).

The frequency and diagnostic accuracy of targetoid restriction in the absence of other targetoid LR-M features is not well known, although one study reported that targetoid restriction is an independent predictor of iCCA.

Targetoid Restriction

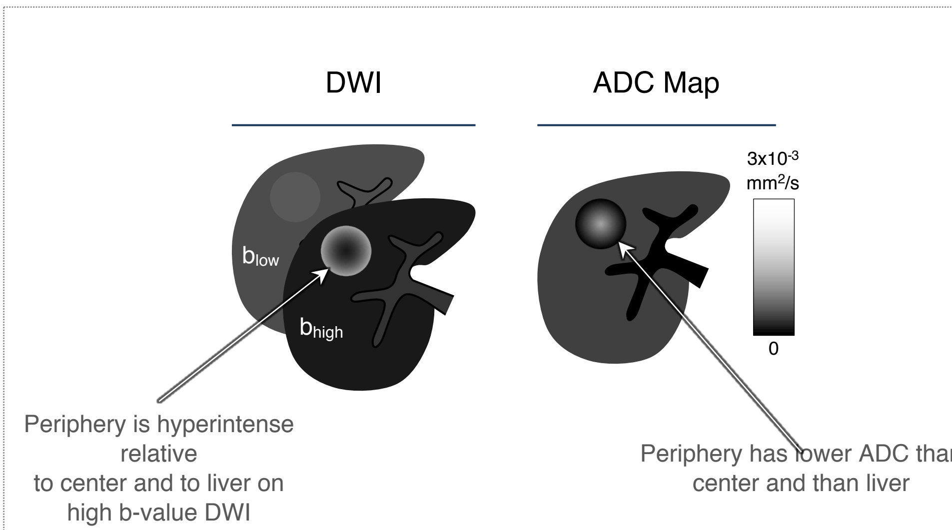
RADLEX ID: N/A

Characterization

Characterize on diffusion-weighted images if obtained and ADC maps if generated.

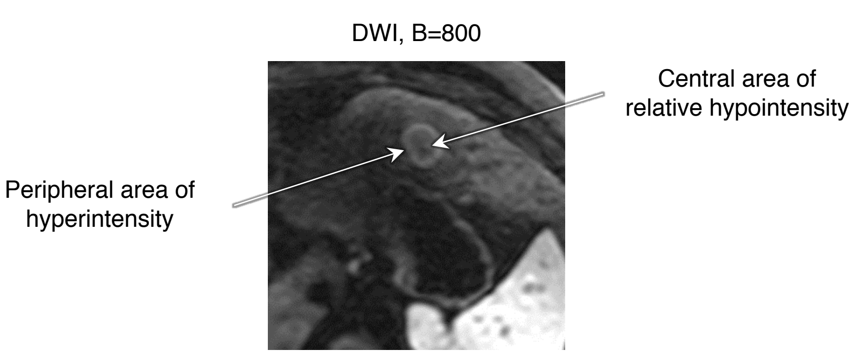
Targetoid restriction is present if the observation periphery

- Is hyperintense relative to observation center and to liver on DW images acquired with at least moderate diffusion weighting (b ≥ 400 s/mm²) **AND**
- Has higher signal than observation center and has similar or lower signal than liver by visual estimation on ADC map



If obtained
(DWI is **not** required by LI-RADS)

Example



Targetoid Restriction

RADLEX ID: N/A

If unsure

If unsure whether there is targetoid restriction, characterize this feature as absent.

Pitfalls & practical considerations

The quality of DWI in the liver is inconsistent, especially in the liver dome (signal loss and spatial distortion due to susceptibility at lung interface) and left lobe (signal loss due to vibrations from heart motion). This feature may be difficult to characterize due to inconsistencies in quality of DWI.

Abscesses and hematomas may have high signal intensity along the periphery, potentially overlapping in appearance with targetoid restriction.

References

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Nontargetoid LR-M Features

RADLEX ID: N/A

Definition

Features other than targetoid that prompt LR-M categorization.

These include

- Infiltrative appearance *(page 16-241)*
- Markedly restricted diffusion *(page 16-241)*
- Necrosis or severe ischemia *(page 16-241)*

Synonyms

Other LR-M features

Terminology

LI-RADS uses the term nontargetoid LR-M features to describe an assortment of imaging features highly suggestive of malignancy but not specific for any particular tumor type.

The term “nontargetoid LR-M features” is preferred over “other LR-M features” since it is less ambiguous.

Applicable modalities

CT, MRI

Type of feature

Assortment of LR-M features highly suggestive of malignancy.

Nontargetoid LR-M Features

RADLEX ID: N/A

Effect on categorization

Each nontargetoid LR-M feature, by itself, is sufficient for LR-M categorization:

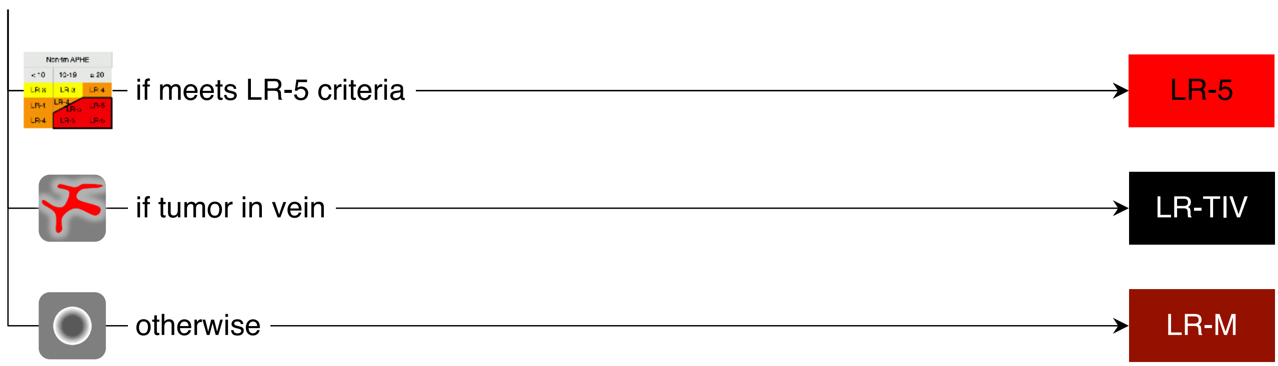
Presence of at least one LR-M feature should prompt LR-M categorization, regardless of other features.

Rationale: Non-targetoid LR-M features are highly suggestive of malignancy but are not specific for any particular tumor type, being commonly encountered in aggressive or poorly differentiated HCCs, as well as in non-HCC malignancies. Since they indicate high probability of malignancy but are not specific for HCC, they should prompt LR-M categorization.

Exceptions:

- If observation is path proven, report path diagnosis, not LI-RADS category.
- If the observation meets LR-5 criteria, categorize as LR-5.
    - Rationale: since the features are commonly encountered in poorly differentiated HCC, their presence does not override LR-5 categorization. Thus, an observation meeting LR-5 criteria and having one or more of these features can be interpreted as definite HCC.
- If there is tumor in vein, categorize as LR-TIV.

Nonpath-proven observation with at least one nontargetoid feature

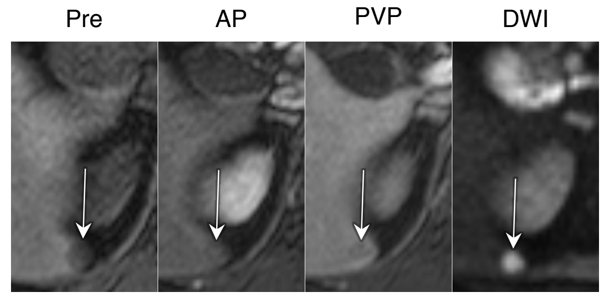


Nontargetoid LR-M Features

RADLEX ID: N/A

Marked diffusion restriction

Intensity on DWI, not attributable solely to T2 shine-through, markedly higher than liver and similar to or greater than spleen; and/or ADC markedly lower than liver and similar to or lower than spleen. Suggests a hypercellular malignant lesion such as iCCA, metastasis, lymphoma, or poorly differentiated HCC. Benign lesions rarely have markedly restricted diffusion.

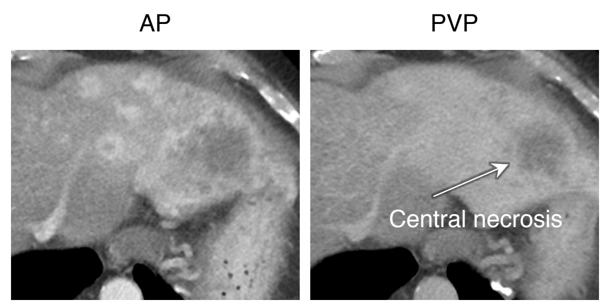


Marked restricted diffusion: Path-proven neuroendocrine metastasis

Necrosis or severe ischemia

Area within a solid mass which either does not enhance at all (necrosis) or enhances very slowly and mildly (ischemia), not attributable to prior treatment. Suggests a poorly differentiated neoplasm that has “outgrown” its blood supply.

Pitfalls: liver abscess may mimic the appearance of a necrotic mass.

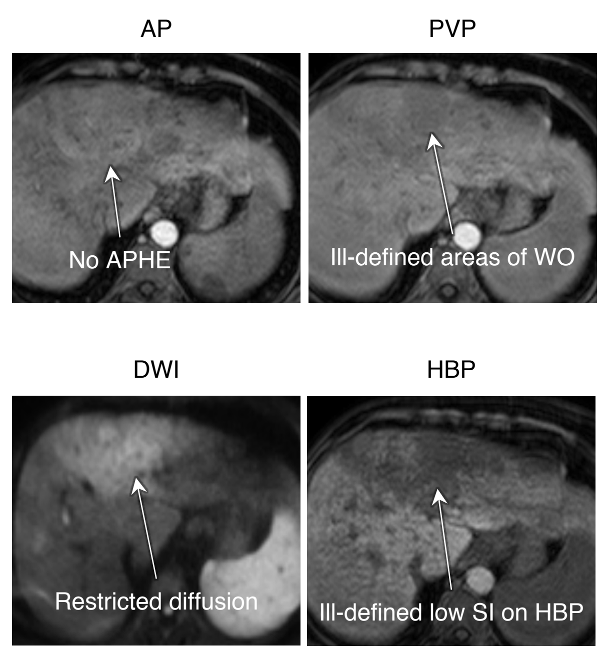


Necrotic mass: Path-proven HCC

Infiltrative appearance

Non-circumscribed margin (indistinct transition) thought to represent malignancy with permeative growth. This is thought to reflect a reflect infiltration of malignant tumor cells into liver parenchyma, confluence of tiny nodules, or both. This is commonly encountered in advanced, poorly differentiated HCC but can sometimes be seen with iCCAs, metastases, and other non-HCC malignancies.

Pitfalls: Some benign processes may have infiltrative appearances and be misinterpreted as malignant. Examples: focal or regional alteration in perfusion, fat deposition, iron deposition. Clue: these do not invade veins, obscure vessels, or distort parenchymal architecture.



Infiltrative appearance: Path-proven HCC

Nontargetoid LR-M Features

RADLEX ID: N/A

Comment

There may be occasions when one or more features not specified above suggests a substantial possibility of non-HCC malignancy. At the radiologist's discretion, such observations should be categorized LR-M. The radiologist should specify in the report the relevant imaging features.

Enhancing Soft Tissue in Vein

RADLEX ID: N/A

Definition

Unequivocal presence of enhancing soft tissue in vein, regardless of presence of parenchymal mass

Synonyms

None

Terminology

Tumor in vein refers to the category LR-TIV

Enhancing soft tissue in vein refers to the imaging feature used to assign the LR-TIV category

Applicable modalities

CT, MRI

Type of feature

Feature of tumor in vein

Effect on categorization

Observations with unequivocal soft tissue in vein are categorized LR-TIV:

- Regardless of presence or appearance of parenchymal mass
- Regardless of any other imaging feature

Exception:

- If the tumor in vein is path proven, report path diagnosis, not LI-RADS category.

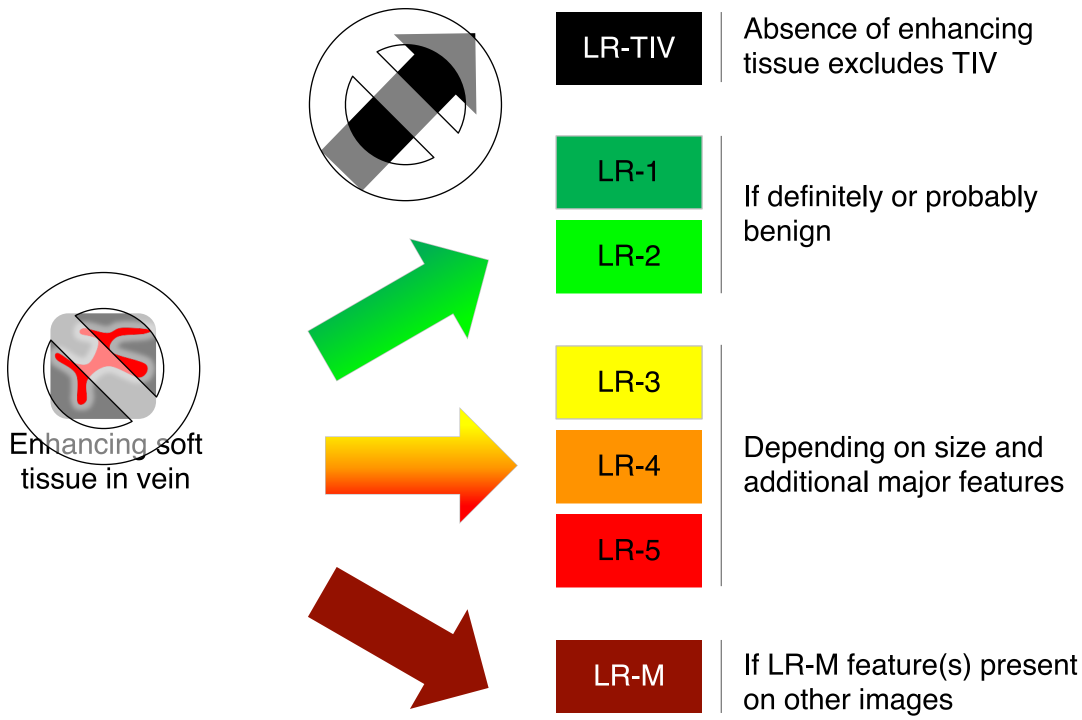
Enhancing Soft Tissue in Vein

RADLEX ID: N/A

Effect on categorization

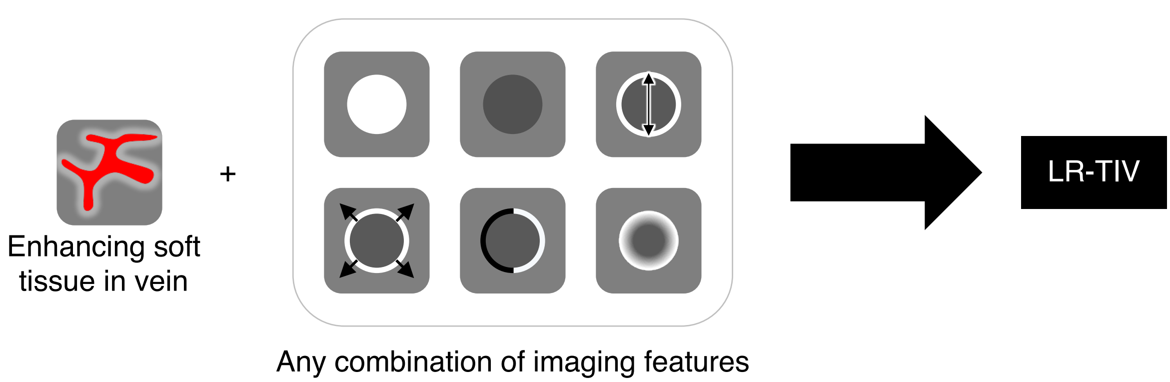
Enhancing soft tissue in vein is required for LR-TIV.

Only observations with enhancing soft tissue in vein can be LR-TIV. As a corollary, the absence of enhancing soft tissue in vein precludes LR-TIV categorization.



Enhancing soft tissue in vein is sufficient for LR-TIV.

Observations with enhancing soft tissue in vein are always categorized LR-TIV.



Enhancing Soft Tissue in Vein

RADLEX ID: N/A

Biological basis

HCCs and less commonly other malignant neoplasms can invade into and grow within the lumen of veins.

HCCs tend to invade the portal veins more commonly than hepatic veins. One plausible explanation is that the blood supplying HCCs drains into sinusoids and portal venules, not hepatic venule. Hence malignant cells that break off from the primary tumor and invade into vessels access the portal venules early in the course of their vascular dissemination, well before they access the lumen of hepatic venules.

Normal blood vessels are filled with blood. The presence of enhancing soft tissue within a vein establishes the presence of a malignant neoplasm within the lumen. Although bland thrombus can fill the lumen, it does not enhance.

Summary of evidence

In a retrospective study of liver transplant patients, enhancement was seen in 100% of tumor in vein cases vs 8.5% of bland thrombi. Neovascularity was seen in 58% of tumor in vein cases vs 2% of bland thrombi.

In a retrospective study of patients with cirrhosis, HCC and portal vein occlusion, arterial enhancement was seen in 44-75% of tumor in vein vs 5-20% of bland thrombi. Arterial enhancement in an occluded vein has 59% sensitivity and 88% specificity for diagnosing a tumor in vein.

In a retrospective study of patients with cirrhosis and portal vein occlusion, neovascularity was seen on CT scans in 43% of patients with tumor in vein and in 0% of patients with bland thrombosis.

Enhancing Soft Tissue in Vein

RADLEX ID: N/A

Characterization

Characterize on any contrast-enhanced phase.

Enhancing soft tissue in vein is present if

- There is soft tissue in the lumen of one or more veins **AND**
- The soft tissue unequivocally enhances

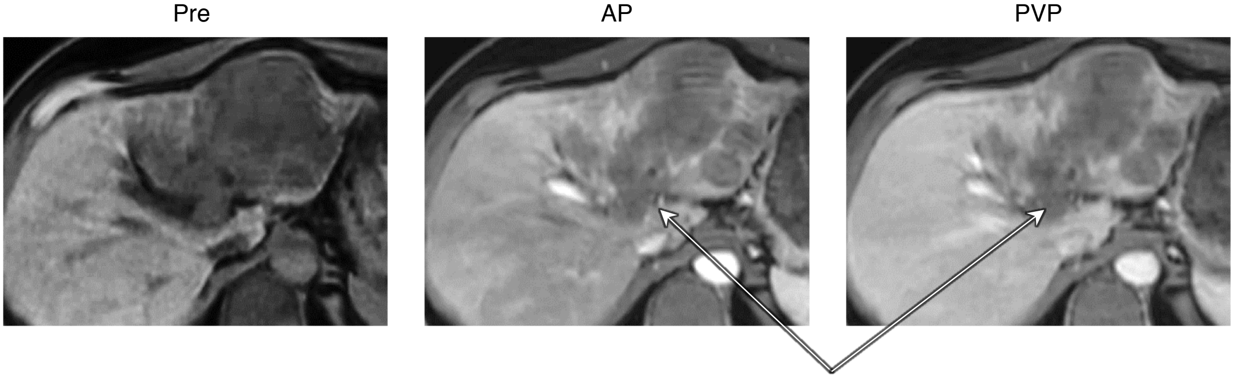
Example: CT

AP PVP DP

Enhancing soft tissue expanding left portal vein

Example: MRI

Pre AP PVP



Enhancing soft tissue expanding left portal vein

Enhancing Soft Tissue in Vein

RADLEX ID: N/A

If unsure

If unsure if there is enhancing soft tissue in vein, characterize as no enhancing tissue in vein.

Pitfalls & practical considerations

Tumor in vein can be present without a parenchymal mass.

Enhancing soft tissue in vein has imperfect sensitivity. Tumor in vein tends to occur with aggressive HCCs, which may have an infiltrative appearance with little if any APHE. Additionally, the intraluminal tumor may become necrotic and not enhance at all.

Collateral vessels around a bland thrombus may resemble enhancing soft tissue in a vein. Do not call enhancing soft tissue in vein if the findings plausibly represent collateral vessels around a bland thrombus.

Acute bland thrombus can expand the vein and resemble “soft tissue”. It does not enhance, however.

Both acute bland thrombus and tumor in vein may have hemorrhagic components, which may have high signal on unenhanced T1W images. Subtraction images may help in assessing enhancement in such cases.

If tumor in vein is suspected but not confirmed at CT or MRI, then expert centers may perform CEUS for further evaluation. CEUS sometimes can establish the presence of tumor in vein when CT or MRI is equivocal. See CUS manual.

Although the most common cause of tumor in vein is HCC, non-HCC malignancies can also invade veins. The following is a general guide for suggesting the etiology:

LR-TIV

- If contiguous with targetoid mass → may be due to non-HCC malignancy
- If contiguous with LR-5 mass → definitely due to HCC
- Otherwise → probably due to HCC

Enhancing Soft Tissue in Vein

RADLEX ID: N/A

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Imaging Features Suggestive of Tumor In Vein

RADLEX ID: N/A

Definition

Features that suggest the presence of tumor in vein but do not establish its presence.

These include

- Occluded vein with ill-defined walls (*page 16-250*)
- Occluded vein with restricted diffusion (*page 16-250*)
- Occluded or obscured vein in contiguity with malignant parenchymal mass (*page 16-250*)
- Heterogeneous vein enhancement not attributable to artifact (*page 16-250*)

Synonyms

None

Terminology

LI-RADS uses the term imaging features suggestive of tumor in vein to describe an assortment of imaging features that suggest but lack the specificity to establish the presence of tumor in vein.

Applicable modalities

CT, MRI

Type of feature

Assortment of features suggestive of tumor in vein

Effect on categorization

These features do not directly affect categorization. Instead, they prompt scrutiny for enhancing soft tissue in vein. If unequivocally present, enhancing soft tissue in vein indicates LR-TIV categorization.

Nonpath-proven observation with at least one imaging feature suggestive of tumor in vein

Scrutinize vein for enhancing soft tissue → if and only if tumor in vein → **LR-TIV**

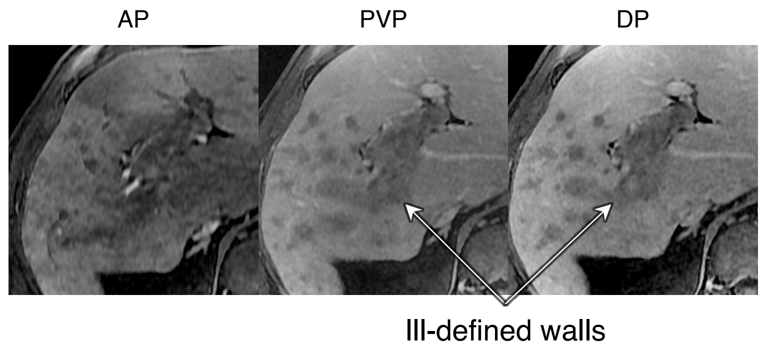
Imaging Features Suggestive of Tumor In Vein

RADLEX ID: N/A

Occluded vein with ill-defined walls

An occluded vein whose walls are poorly demarcated without a sharp demarcation between vein and surrounding parenchyma.

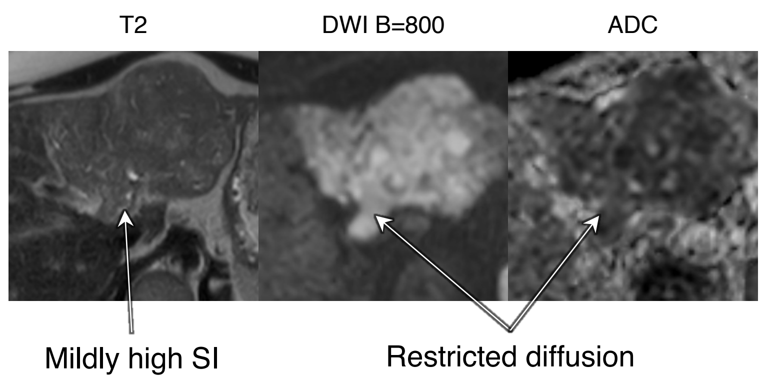
Pitfall: This is not specific for tumor in vein. It can occur in acute bland thrombus.



Occluded vein with restricted diffusion

An occluded vein with intensity on DWI, not attributable solely to T2 shine-through, unequivocally higher than liver and/or ADC unequivocally lower than liver.

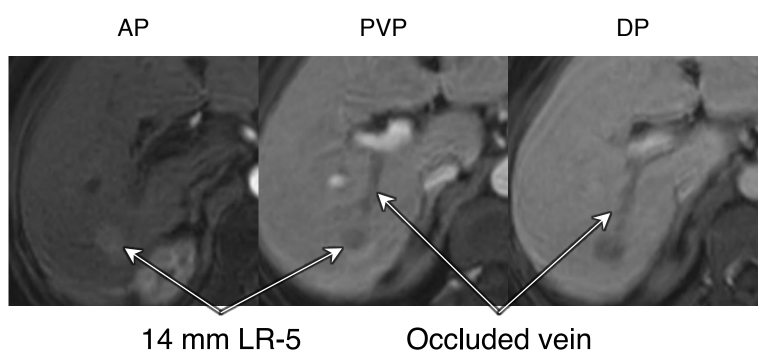
Pitfall: This is not specific for tumor in vein. It can occur in acute bland thrombus.



Occluded or obscured vein in contiguity with malignant parenchymal mass

An occluded vein that contacts a LR-5, LR-M, or path-proven malignant neoplasm in the liver parenchyma.

Pitfall: This is not specific for tumor in vein. It can occur in bland thrombus.



Heterogeneous vein enhancement not attributable to artifact

Heterogeneous enhancement in the lumen of a vein that is not attributable to flow, mixing, or other artifact.

Imaging Features Suggestive of Tumor In Vein

RADLEX ID: N/A

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Ancillary Features

Ancillary Features Favoring Malignancy in General

Ancillary Imaging Features Favoring Malignancy in General & Imaging Modalities in Which They Are Visible

Ancillary features favoring malignancy, not HCC in particular

Feature	Definition	CT	MRI ECA	MRI HBA
US visibility as discrete nodule	Unenhanced US visibility as discrete nodule or mass corresponding to CT- or MRI-detected observation	+	+	+
Subthreshold growth	Unequivocal size increase of a mass, less than threshold growth. See page 16-175 for definition of threshold growth.	+	+	+
Corona enhancement	Periobservational enhancement in late arterial phase or early PVP attributable to venous drainage from tumor	+	+	+
Fat sparing in solid mass	Relative paucity of fat in solid mass relative to steatotic liver **OR** in inner nodule relative to steatotic outer nodule	+ / –	+	+
Restricted diffusion	Intensity on DWI, not attributable solely to T2 shine-through, unequivocally higher than liver and/or ADC unequivocally lower than liver	–	+	+
Mild-moderate T2 hyperintensity	Intensity on T2WI mildly or moderately higher than liver and similar to or less than non-iron-overloaded spleen	–	+	+
Iron sparing in solid mass	Paucity of iron in solid mass relative to iron-overloaded liver **OR** in inner nodule relative to siderotic outer nodule	–	+	+
Transitional phase hypointensity	Intensity in the transitional phase unequivocally less, in whole or in part, than liver	–	–	+
Hepatobiliary phase hypointensity	Intensity in the hepatobiliary phase unequivocally less, in whole or in part, than liver	–	–	+

\+ usually evaluable – not evaluable + / – may or may not be evaluable

ADC = apparent diffusion coefficient, *ECA* = extracellular agent, *DWI* = diffusion-weighted imaging, *HBA* = hepatobiliary agent, *PVP* = portal venous phase, *T2WI* = T2-weighted imaging

US Visibility as Discrete Nodule

RADLEX ID: N/A

Definition

An observation visible on unenhanced US as discrete nodule or mass unequivocally corresponding to CT- or MRI-detected observation

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Synonyms

US detectability as discrete nodule, sonographic visibility as discrete nodule

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Terminology

Not applicable

Applicable modalities

CT, MRI

Type of feature

Ancillary imaging feature favoring malignancy in general, not HCC in particular

---

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then US visibility as discrete nodule causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, US visibility as discrete nodule cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

Biological basis

Visibility on US confirms that an observation is a space-occupying mass.

US Visibility as Discrete Nodule

RADLEX ID: N/A

Summary of evidence

The diagnostic performance of US visibility as discrete nodule, in combination with major features, is unknown.

The reported per-patient specificity of unenhanced US in a surveillance setting is 89%.

US visibility incrementally increases the probability of HCC, as demonstrated by the data below using **LI-RADS v2013** in adults with cirrhosis and :

- 96% of 10-19 mm LR-4 observations with US visibility are HCC.
- 69% of 10-19 mm LR-3 observations with US visibility are HCC.
- 25% of 10-19 mm LR-2 observations with US visibility are HCC.

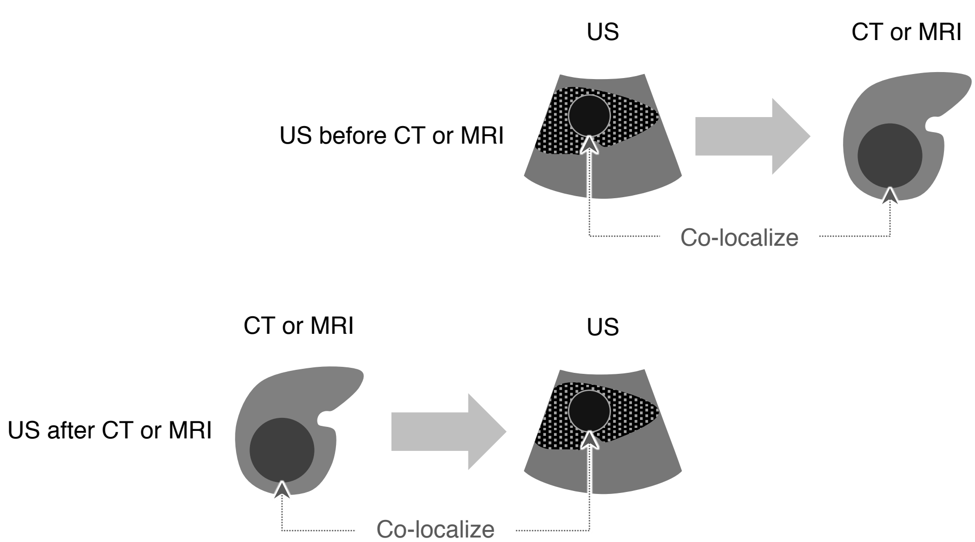
These probabilities are higher than the corresponding probabilities associated with observations without US visibility.

Characterization

Compare CT or MR images with US images, co-localizing using anatomic landmarks.

To qualify as US visibility as discrete nodule, the observation visualized on CT or MRI must correspond unequivocally to a discrete nodule detected at US.

The US can be performed before or after the CT or MRI.



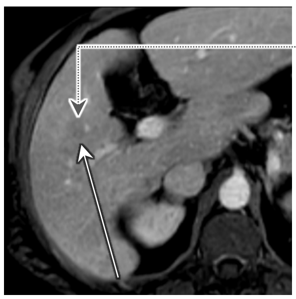
US Visibility as Discrete Nodule

RADLEX ID: N/A

Example

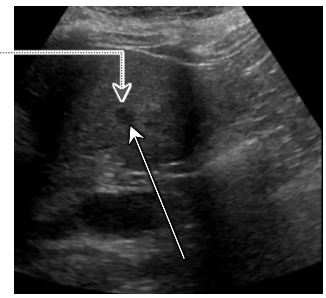
11 mm observation with PVP “washout” and US visibility

Contrast-enhanced MRI, PVP



Co-localize

US



PVP “washout”

Major feature of HCC

Observation visible as discrete nodule on US

Ancillary feature favoring malignancy in general

LR-3 → If ancillary feature is applied → LR-4

If unsure

If unsure about US visibility as discrete nodule, do not characterize as US visibility as discrete nodule.

Pitfalls & practical considerations

Establishing unequivocal correspondence between US nodule and CT/MRI observation may be difficult.

If an LR-3 observation is detected at CT or MRI, it may be reasonable to perform an US exam to assess US visibility. US visibility can upgrade the category to LR-4. Additionally, if multidisciplinary discussion leads to a decision to perform biopsy, then US can be used for guidance.

Focal fat sometimes may have a rounded shape and be misinterpreted at US as a discrete nodule.

US Visibility as Discrete Nodule

RADLEX ID: N/A

References

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Subthreshold Growth (STG)

RADLEX ID: N/A

Definition

Unequivocal growth of a mass, less than threshold growth, i.e.,

- < 50% in ≤ 6 months
- Any unequivocal growth in > 6 months
- Unequivocally new mass of any size in any time interval

Synonyms

Subthreshold diameter increase, subthreshold size increase, growth less than threshold

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Terminology

Not applicable

Applicable modalities

CT, MRI

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular

---

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then subthreshold growth causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, STG cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

Subthreshold Growth (STG)

RADLEX ID: N/A

Biological basis

Uncontrolled growth is a defining feature of malignancy: virtually all premalignant and malignant neoplasms grow, although the rate of growth is variable, reflecting the biological potential of a tumor and its blood supply as well as its degree of de-differentiation. By comparison, benign lesions tend to remain stable or grow slowly over time; in the cirrhotic liver, some benign lesions such as hemangiomas may even become smaller over time (see *Chapter 15, page 6* and page 16-49 for discussion of sclerosing hemangiomas).

Since malignant neoplasms grow more frequently and rapidly than benign lesions, growth favors malignancy. If the growth exceeds a threshold (≥ 50% growth in ≤ 6 months), it is considered threshold growth and is a major feature of HCC. If the growth does not meet the threshold, it is considered subthreshold and is an ancillary feature favoring malignancy.

Summary of evidence

The diagnostic performance of subthreshold growth as a standalone feature has a sensitivity of 48% and specificity of 91% for the diagnosis of HCC a high-risk population. The incremental impact on diagnostic performance of subthreshold growth in combination with major features is unknown.

Data on growth rates and tumor volume doubling times (TVDTs) provide partial supporting evidence:

- The growth rate of HCC in cirrhotic liver (reported upper limit of TVDT is 1.1-2.4 years) exceeds the growth rate of hemangiomas in noncirrhotic liver. Since hemangiomas grow even more slowly (and sometimes involute) in cirrhosis, the differential in cirrhosis is expected to be even more pronounced.

- The growth rate of HCC precursor nodules in cirrhosis is variable, with mean TVDT varying from 90 days to over one year.

- Growth rate in low grade dysplastic nodules is lower than in high grade dysplastic nodules (46% vs 69% size increase in 100 months, respectively).

- Growth rates in iCCA and cHCC-CCA are not well-established, as such tumors are not usually followed by serial imaging studies.

Subthreshold Growth (STG)

RADLEX ID: N/A

Characterization

STG should be characterized on serial CT or MR exams performed on different dates.

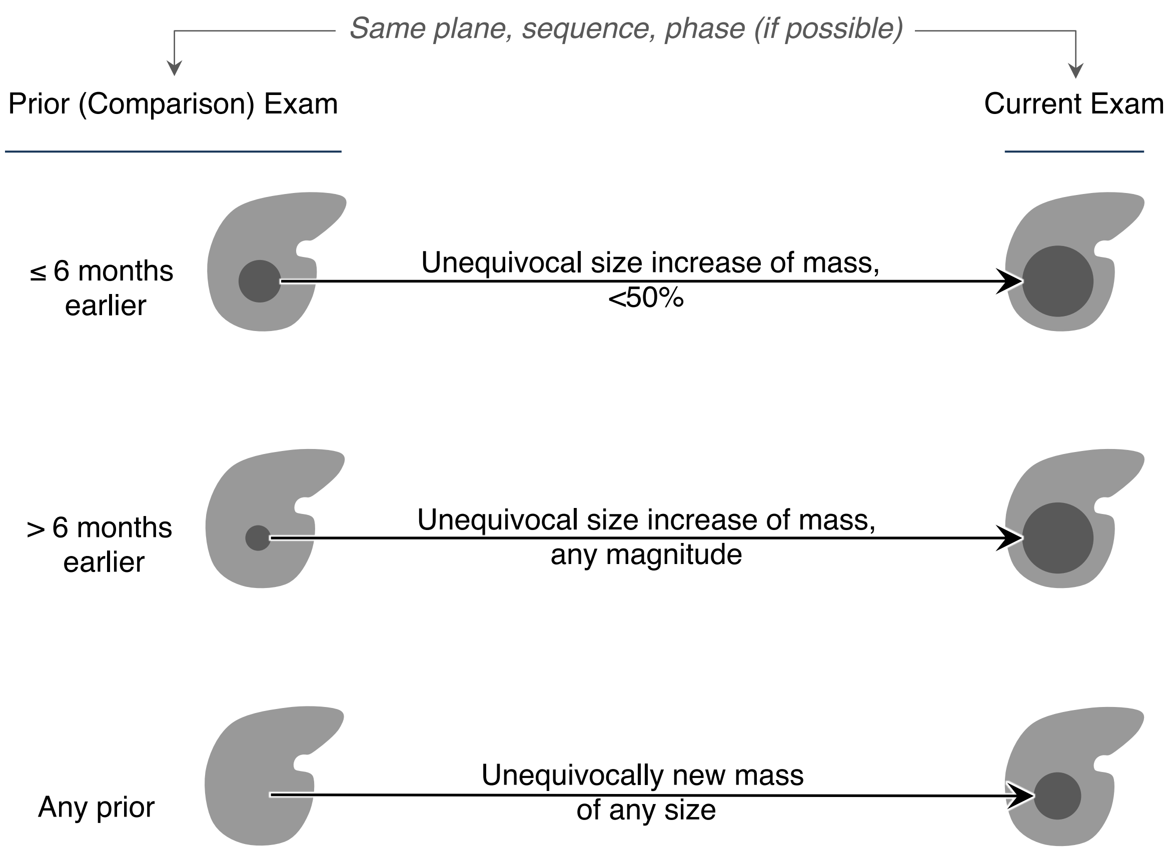
If possible, measure on images where observation margins are clearest and in same plane, sequence, phase. If modalities vary over time, select a common phase or sequence.

STG applies only to masses. Do not apply STG to nonmass lesions (such as focal fat) or pseudolesions (such as perfusion alterations)

STG is present if **ALL** of the following criteria are met:

- Mass is measurably larger on later than earlier exam **AND**
- Increase in size is not attributable to artifact, measurement error, or technique differences **AND**
- The growth does not meet the criterion for threshold growth

An unequivocally new mass since a prior exam also qualifies as STG.



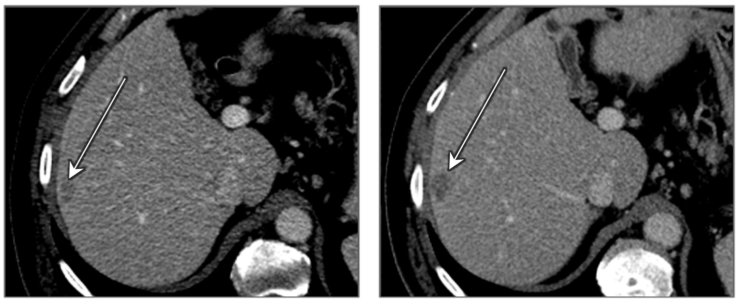
Subthreshold Growth (STG)

RADLEX ID: N/A

Characterization (Cont'd)

Example: CT

Initial CT | 6 months follow-up CT



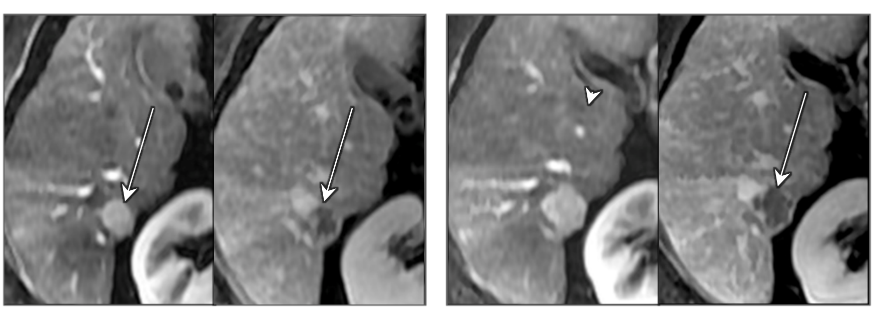
Size: 12 mm | Size: 16 mm

33% size increase in
6 months is STG

Example: MRI

Initial MRI | 3.5 months follow-up MRI

AP | PVP | AP | PVP



Size: 16 mm | Size: 21 mm

31% size increase in
3.5 months is STG

Subthreshold Growth (STG)

RADLEX ID: N/A

If unsure

If unsure about STG vs. no growth, characterize as no growth.

If unsure about STG vs. threshold growth, characterize as STG.

If unsure if observation is a mass, do not apply STG.

Pitfalls and practical considerations

Arterial phase (AP) and DWI are unreliable for measuring growth:

- AP: slight timing changes may cause substantial differences in apparent size
- DWI: spatial distortion introduces measurement error

Avoid the arterial phase and DWI for measurements if margins are clearly visible on other phases and sequences, respectively.

Applies only to masses.

- Multiplanar images (source or reformatted) may help determine whether the observation is a mass.

No minimum size requirement. Instead, the presence of growth must be unequivocal in radiologist's judgment

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Subthreshold Growth (STG)

RADLEX ID: N/A

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Corona Enhancement

RADLEX ID: RID39442

Definition

Peri-observational enhancement in late arterial phase or early PVP attributable to venous drainage from tumor.

Synonyms

Corona, perilesional staining

Terminology

The term "corona enhancement" refers to a specific type of peri-observational enhancement attributable to venous drainage. It does not refer to peri-observational enhancement attributable to arterioportal shunting.

Applicable modalities

CT, MRI (all contrast agents)

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular

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Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then corona enhancement causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, corona enhancement cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

Corona Enhancement

RADLEX ID: RID39442

Biological basis

Proliferation of neoplastic cells leads initially to destruction of intralesional hepatic veins and later to compression of perilesional hepatic veins. Since the physiologic pathways for venous return are removed, tumor blood drains into the surrounding sinusoids and portal venules. If the tumor is hyper enhancing in the arterial phase, then the blood draining the tumor will also be hyperenhancing, leading to corona enhancement. Lagging slightly behind the peak of the tumor enhancement, the corona is typically most pronounced in the late arterial or early portal venous phase.

Corona enhancement is not specific for HCC and can occur with any hypervascular neoplasm with peritumoral neovascularization.

Summary of evidence

The incremental impact on diagnostic performance of corona enhancement in combination with major features is unknown.

Based on high-temporal resolution CT hepatic arteriography and multi-arterial phase MRI, corona enhancement can be detected in 66-89% of HCCs, and in 71% the corona is thick. Corona enhancement is not observed in arterioportal shunts.

The frequency of corona enhancement in HCC is not known for CT and MRI performed after intravenous contrast injection.

Corona Enhancement

RADLEX ID: RID39442

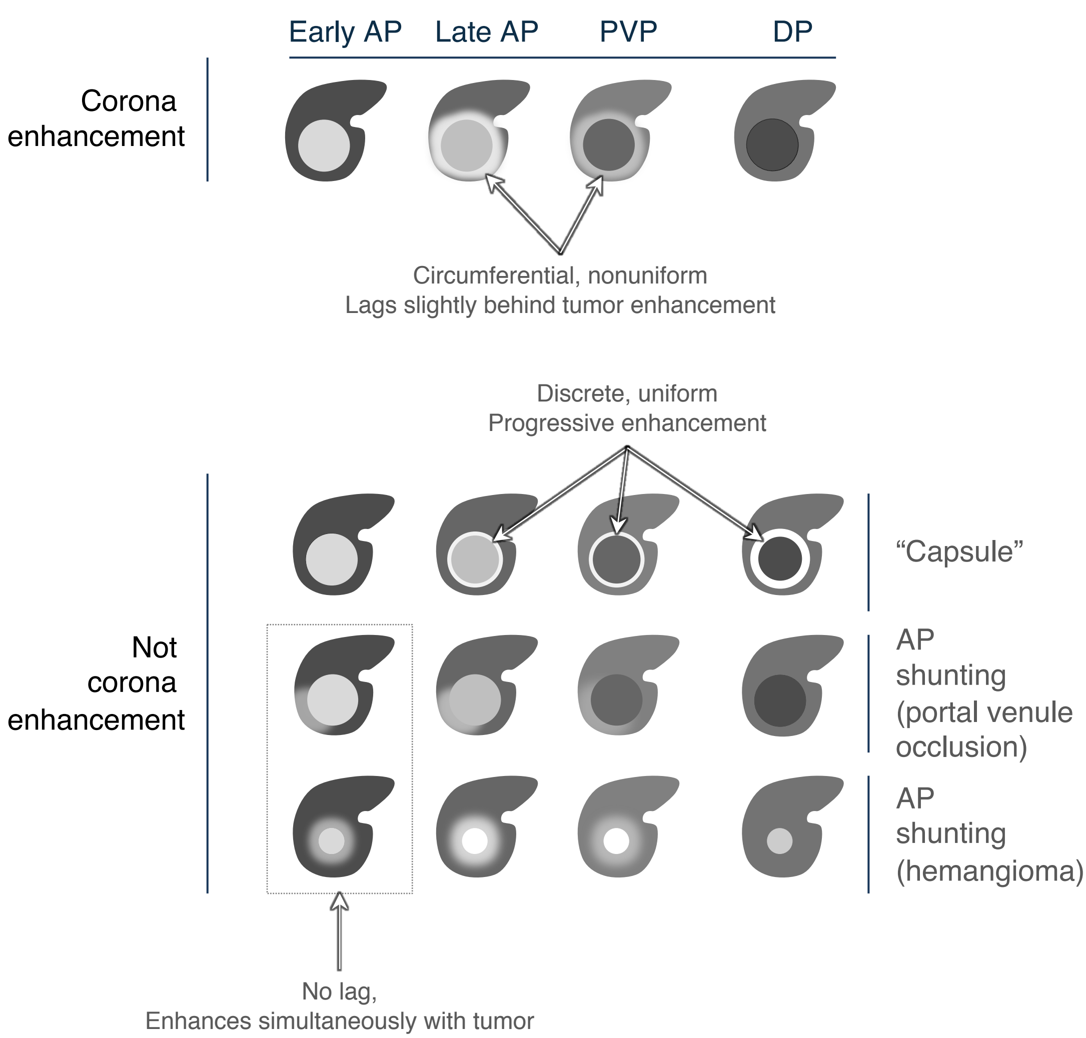
Characterization

Corona enhancement should be characterized on multiphase CT or MRI.

Corona enhancement is present if **ALL** of the following are met:

- Circumferential or eccentric rim of periobservation enhancement **AND**
- Appears in late arterial phase or early portal venous phase then fades to isoenhancement on later phases **AND**
- Associated observation shows APHE

Since it is caused by venous drainage of contrast-enhanced blood form the tumor, the corona enhancement typically lags slightly behind the tumor enhancement.



Corona Enhancement

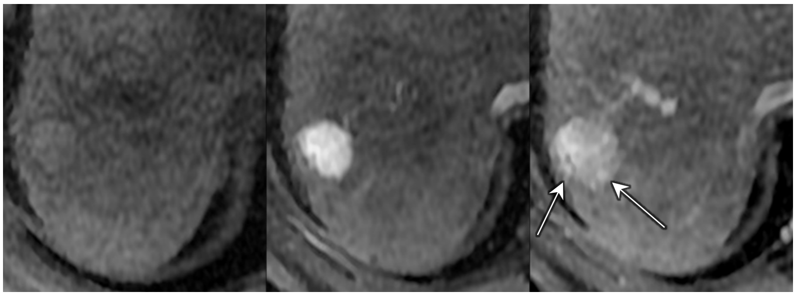
RADLEX ID: RID39442

Characterization (Cont'd)

Example: CT

Corona enhancement
in AP

Example: MRI



Corona enhancement
in late AP

If unsure

If unsure about corona enhancement, do not characterize as corona enhancement.

Corona Enhancement

RADLEX ID: RID39442

Pitfalls & practical considerations

Corona is assessed most reliably if multiple high-temporal-resolution arterial phases are acquired, which demonstrate the characteristic temporal profile.

If only a single arterial phase is acquired, corona may not be recognized even if present.

- In early AP, for example, corona may be imperceptible as contrast material has not yet drained from the lesion.
- In late AP, corona enhancement may blend in with the enhancement of the lesion ("summation"), causing size overestimation.

To avoid size overestimation from summation enhancement, do not measure observation size in AP if margins are clearly seen on other phases (see page 16-165).

Corona should be differentiated from enhancing "capsule" and periobservation AP shunting.

- Corona enhancement appears in late AP or early PVP, then fades to isoenhancement in late PVP and DP. It may be circumferential or eccentric and it may vary in thickness and uniformity. Confined to the parenchyma immediately adjacent to the observation, it is rarely extensive. Since it represents venous drainage from a hypervascular tumor into the surrounding parenchyma, the associated observation always shows APHE.
- Enhancing "capsule" shows progressive enhancement, and is usually a uniformly thick discrete structure. The associated observation may or may not show APHE. Some observations may have both corona enhancement and enhancing "capsule". In such cases, the presence of corona enhancement may be difficult to ascertain.
- Arterioportal shunting refers to the rapid flow of contrast-enhanced arterial blood into portal veins or venules and their corresponding vascular territory(ies). Since the blood enters via the artery, arterioportal shunts enhance in the early AP and then fade. Reflecting their territorial distribution, they are typically geographic or wedge shaped, with straight borders. Depending on the location and size of the shunt, they may be extensive.

The differentiation from AP shunting can be particularly difficult. The table on next page summarizes characteristics to help differentiate corona from AP shunting.

Corona Enhancement

RADLEX ID: RID39442

Pitfalls & practical considerations (Cont'd)

Table: differentiation of corona from AP shunting

	Corona	AP shunting
Temporal pattern	Enhances in late AP or early PVP, then fades. Lags behind tumor enhancement.	Enhances in early AP, then fades. Does not lag behind tumor enhancement.
Shape	Concentric or circumferential	Geographic or wedge
Thickness	Variable, rarely if ever extensive	Variable, may be extensive
Associated observation	Always shows APHE	May or may not show APHE

Since seeding of daughter or satellite nodules forms in the peritumoral venous drainage area, the corona enhancement territory is a "high-risk" area for the presence of microscopic metastases. To reduce the risk of local recurrence after hepatectomy and locoregional treatment, it should be included within the surgical margin and in the ablation zone, respectively.

Corona Enhancement

RADLEX ID: RID39442

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Fat Sparing in Solid Mass

RADLEX ID: RID43347

Definition

Relative paucity of fat in solid mass compared to steatotic liver OR in inner nodule relative to steatotic outer nodule.

Synonyms

Lesional fat sparing

Terminology

Fat sparing in solid mass is preferred since it emphasizes that this feature should be applied only for solid masses.

Applicable modalities

CT, MRI (all contrast agents)

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then fat sparing in solid mass causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy in general, fat sparing in solid mass cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

Biological basis

Paucity of fat suggests clonal expansion of dysplastic or malignant cells different from surrounding cells. By comparison, benign cells do not proliferate clonally and tend to have similar phenotypic properties as their neighbors.

Fat Sparing in Solid Mass

RADLEX ID: RID43347

Summary of evidence

The incremental impact on diagnostic performance of fat sparing in a solid mass in combination with major features is not known.

Evidence supporting this feature is indirect.

- Pathology studies have shown the progressed HCCs are rarely steatotic (exception steatohepatic variant), whereas early HCCs and dysplastic nodules are frequently steatotic.
- Additionally, fat accumulation is exceptionally rare in cholangiocarcinoma and other non-HCC malignancies.

Fat Sparing in Solid Mass

RADLEX ID: RID43347

Characterization

On MRI:

Characterize on out-of-phase (OP) compared to in-phase (IP) gradient-echo images.

If obtained, can also characterize on fat-only images, **OR** fat-fraction maps, **OR** fat-suppressed compared to otherwise similar non-fat-suppressed images (not shown in schematic below)

Fat sparing in solid mass is present if **ALL** of the following are met:

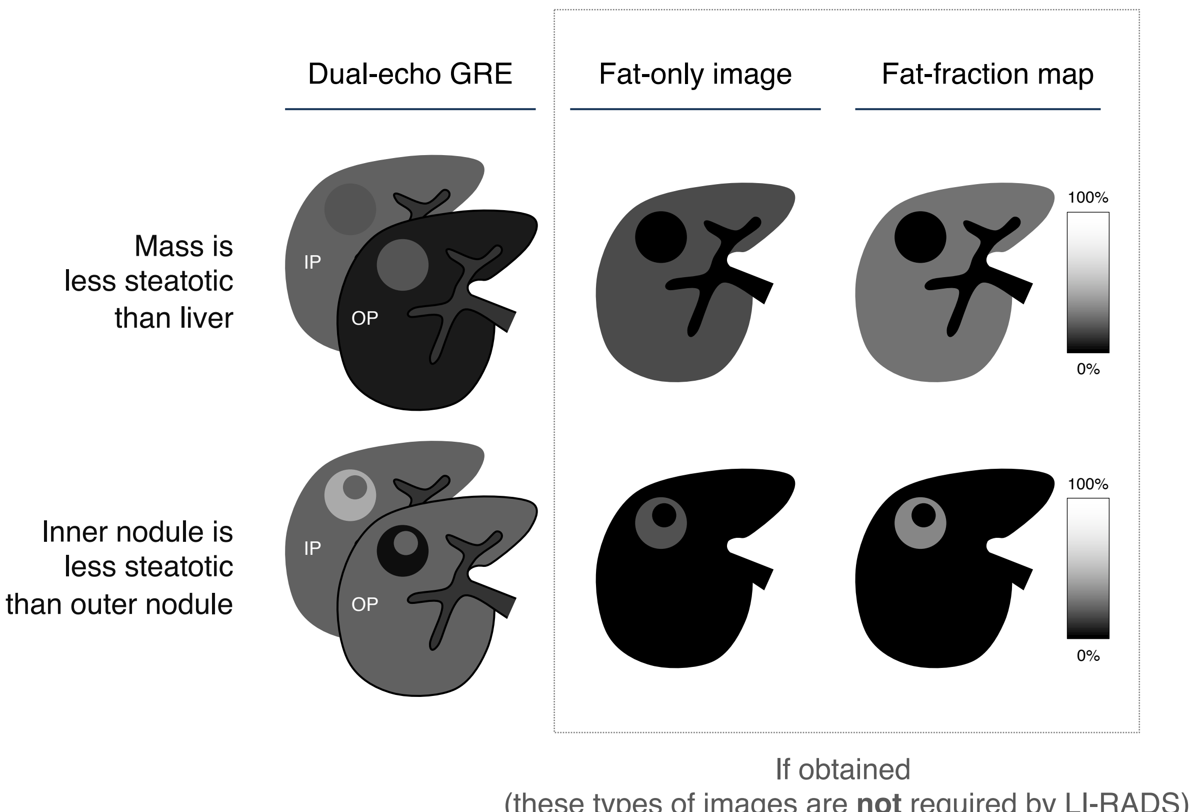
- The observation is a mass

  AND

- the liver (or outer nodule) is steatotic as evidenced by unequivocal signal loss on OP compared to IP **OR** fat signal on fat-only images, **OR** positive fat fraction on fat-fraction maps, **OR** signal loss on fat-suppressed compared to non-fat-suppressed (not shown in schematic below)

  AND

- the observation (or inner nodule) is less steatotic or nonsteatotic (less or no signal loss, lower or no fat signal, or lower or zero fat fraction on the corresponding images or maps)



Fat Sparing in Solid Mass

RADLEX ID: RID43347

Characterization (Cont'd)

On CT:

With caution, this feature sometimes can be characterized on CT:

Fat sparing in solid mass is present on CT if **ALL** of the following are met:

- The observation is a solid mass

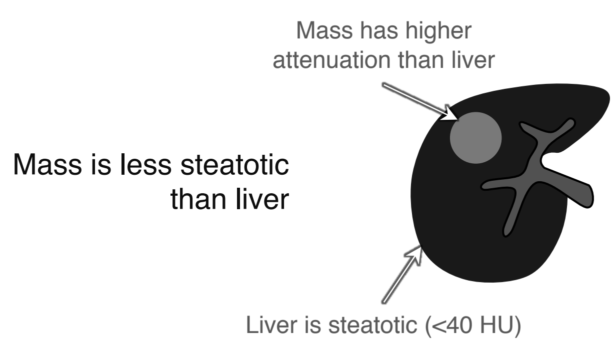
  AND

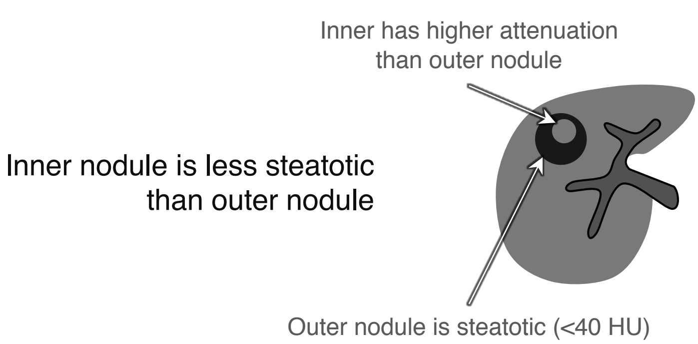
- the liver (or outer nodule) is steatotic (attenuation < 40 HU)

  AND

- the observation (or inner) nodule is less steatotic or nonsteatotic (attenuation ≥ 40 HU).

CT

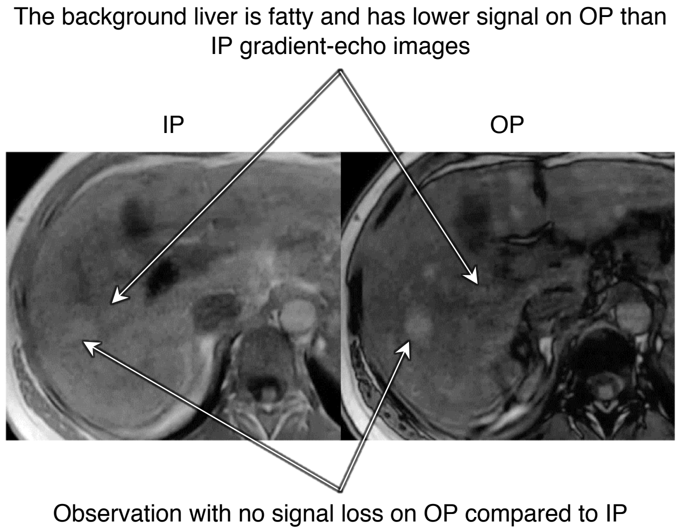




Fat Sparing in Solid Mass

RADLEX ID: RID43347

Example: MRI



Example: CT

Fat Sparing in Solid Mass

RADLEX ID: RID43347

If unsure

If unsure about fat sparing in solid mass, do not characterize as fat sparing in a solid mass.

Pitfalls & practical considerations

Applies only to solid masses. (See *Chapter 7, page 5).*

- Do not apply to nonsolid lesions like cysts or hemangiomas.
- Multiplanar images (source or reformatted) may help determine whether the observation is a mass.

Fat sparing in solid mass fat needs to be differentiated from hepatic fat sparing.

Imaging features that favor fat sparing in solid mass over hepatic fat sparing:

- Observation is a mass (See *Chapter 7, page 5*).
- Enhancement differs from that of background liver in one or more postcontrast phases and the difference is not attributed to a perfusion alteration.

Perfusional alterations can be associated with hepatic fat sparing. Do not apply fat sparing as an ancillary feature favoring malignancy if you suspect the observation represents a perfusional alteration and not a mass.

Any benign nonhepatocellular lesion (cyst, hemangioma, confluent fibrosis) contains less fat than surrounding steatotic liver. Do not apply fat sparing as an ancillary feature favoring malignancy if the lesion is thought to be one of these benign entities.

MRI is more sensitive and specific for detection of fat sparing in solid mass than CT. Apply this feature cautiously on CT.

References

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Restricted Diffusion

RADLEX ID: RID43349

Definition

Intensity on DWI, not attributable solely to T2 shine-through, unequivocally higher than liver and/or ADC unequivocally lower than liver

Synonyms

Impeded diffusion, diffusion restriction, high DWI signal.

Terminology

Restricted diffusion is the preferred term as it is the most commonly used term in the literature. High DWI signal is imprecise because it may reflect T2 shine through rather reduced molecular motion.

Applicable modalities

MRI

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then restricted diffusion causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, restricted diffusion cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: if the restricted diffusion has a targetoid morphology, the imaging feature should be characterized as targetoid DWI (a LR-M feature) and the observation should be categorized LR-M. See *page 16-234*.

Restricted Diffusion

RADLEX ID: RID43349

Biological basis

Signal intensity of a tissue on DWI depends on random motion of water molecules. Molecules confined within small cells are more restricted in their motion than molecules confined within large cells, which in turn are more restricted in their motion than molecules in the extracellular space. Malignant neoplasms are associated with a high density of relatively small cells, with reduced extracellular volume. This architecture causes reduced molecular mobility and restricted diffusion.

Summary of evidence

Studies have shown improved accuracy in HCC diagnosis when DWI is combined with contrast-enhanced MRI:

- Using histology as reference, hyperintensity on DWI (b ≥ 500 s/mm^2) incrementally increases the sensitivity of APHE + “washout” for diagnosis of HCC from 60%–62% to 70%–80%.
- Using histology as reference, hyperintensity on DWI (b ≥ 500 s/mm^2) incrementally increases the accuracy of contrast-enhanced MRI for differentiating HCC from dysplastic nodule from 76% to 93%.

Hypovascular nodules that are hyperintense on DWI have a higher risk of transformation to hypervascular HCCs (HR 7.4; 95% CI 4.3 -12.9).

There is a general trend towards higher histologic grade with increasing restricted diffusion.

Restricted Diffusion

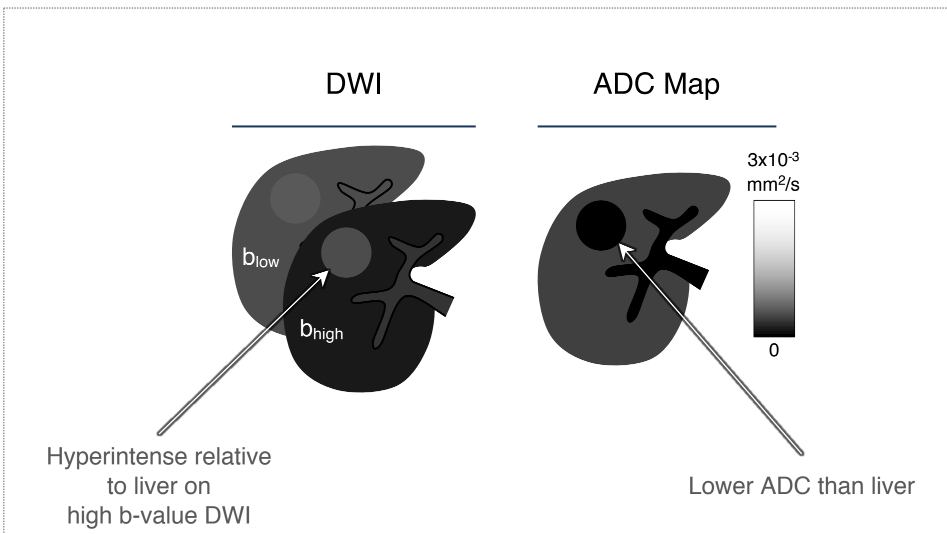
RADLEX ID: RID43349

Characterization

Characterize on diffusion-weighted images if obtained and ADC maps if generated.

Restricted diffusion is present if the observation

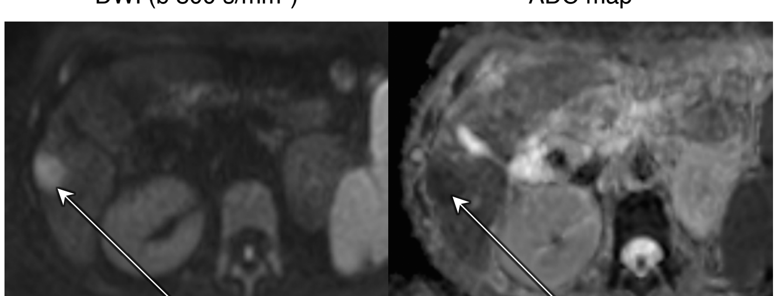
- Is hyperintense relative to liver on DW images acquired with at least moderate diffusion weighting ($b \geq 400$ s/mm^2) **AND**
- Has similar or lower signal than liver by visual estimation on ADC map



If obtained
(DWI is **not** required by LI-RADS)

Example

DWI (b 800 s/mm^2) | ADC map



High signal relative to liver | Low signal relative to liver

Restricted Diffusion

RADLEX ID: RID43349

If unsure

If unsure about restricted diffusion, do not characterize as restricted diffusion.

Pitfalls & practical considerations

DWI is not as sensitive to HCC as it is to iCCA or liver metastases. As a result, isointensity or faint hyperintensity on DWI does not exclude HCC.

"Restricted" diffusion may be attributable to true restriction, to hindrance, or to both. Current diffusion weighted imaging technology does not reliably differentiate between these possibilities and the term "restriction" is used loosely to apply to both mechanisms.

Since ADC values depend on the scanner, field strength, acquisition technique, and exponential model, caution is advised when applying published ADC thresholds for clinical care.

When interpreting ADC maps for small (<10 mm) observations, make sure each b-value image is co-localized. Small changes in observation location between b-values can lead to gross errors in the mapped ADC values.

High signal on DWI may represent T2 shine through rather than restricted diffusion. ADC maps can help in the differentiation: ADC values lower than liver indicate restricted diffusion.

The morphological pattern of restriction can be important. For example, targetoid appearance on DWI is a LR-M feature (see *page 16-234*).

The degree of restriction can be important. For example, marked diffusion restriction is a LR-M feature (see *page 16-241*).

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 postcontrast. 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.

Restricted Diffusion

RADLEX ID: RID43349

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Mild-moderate T2 Hyperintensity

RADLEX ID: RID39468

Definition

Signal intensity on T2-weighted images mildly or moderately higher than liver and similar to or less than non-iron-overloaded spleen.

Synonyms

Slightly bright T2, mild-moderate T2 signal

Terminology

Mild-moderate T2 hyperintensity is preferred since it is consistent with general LI-RADS terminology.

Applicable modalities

MRI (all contrast agents)

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then mild-moderate T2 hyperintensity causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, mild-moderate T2 hyperintensity cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

Biological basis

The biological basis is not well understood. T2 hyperintensity may reflect intratumoral dilated sinusoids and edema. Signal on T2W images correlates with intra-nodular arterial flow and inversely with intra-nodular portal venous flow, pathophysiological alterations associated with hepatocarcinogenesis.

Mild-moderate T2 Hyperintensity

RADLEX ID: RID39468

Summary of evidence

The evidence supporting mild-moderate T2 hyperintensity as an ancillary feature favoring malignancy is indirect and inconsistent:

- 83-86% of all HCCs have T2 hyperintensity.
- 36-53% of well-differentiated HCCs have T2 hyperintensity.
- 70-85% of cHCC-CCAs have T2 hyperintensity.
- 12-68% of iCCAs have T2 hyperintensity
    - 44-68% diffusely
    - 24-44% peripherally
    - 12-63% centrally
- 38% of histologically sampled high-grade dysplastic nodules have T2 hyperintensity
- 12% of histologically sampled low-grade dysplastic nodules have T2 hyperintensity.
- The percentage of regenerative nodules with T2 hyperintensity is unknown but is generally assumed to be negligible.
- For differentiation of HCC without APHE from dysplastic nodule: mild-moderate T2 hyperintensity in combination with DWI has a sensitivity of 72% and specificity of 100%.
- HCCs with higher histopathologic grade are more likely to be T2 hyperintense.
- HCC with infiltrative appearance is often T2 hyperintense, even in the absence of APHE.
- However, in a multivariate analysis, T2 hyperintensity is not an independent predictor of HCC. T2W imaging does not meaningfully increase diagnostic accuracy for HCC because this feature is usually seen in progressed HCCs and therefore occurs in association with other major or ancillary features.

Although T2 hyperintensity is associated with progressed HCC, it can be seen in precursor nodules and nodules without APHE, in which case it may have prognostic significance:

- In precursor nodules: T2 hyperintensity is associated with higher growth rates.
- In initially non-hyperenhancing nodules: T2 hyperintensity is an independent risk factor for future hypervascularization.

The incremental impact on diagnostic performance of mild-moderate T2 hyperintensity in combination with major features is not known.

Mild-moderate T2 Hyperintensity

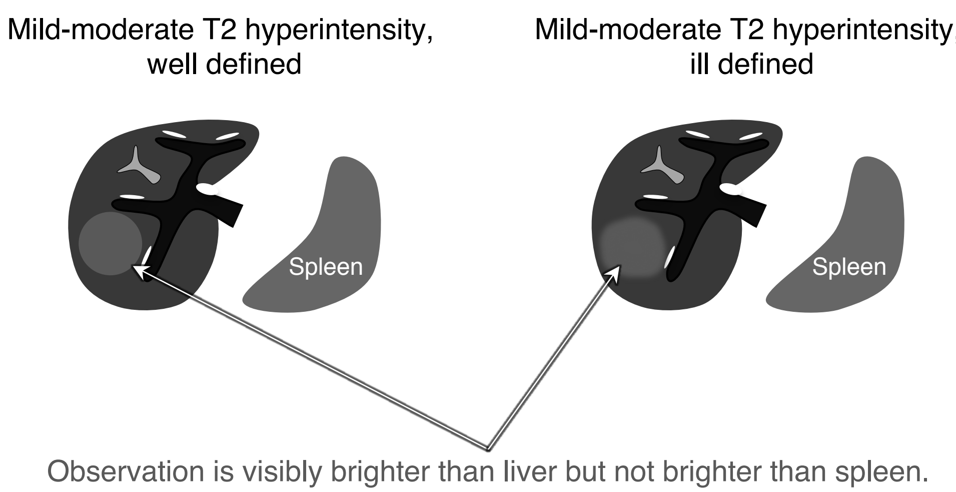
RADLEX ID: RID39468

Characterization

Characterize on T2W images.

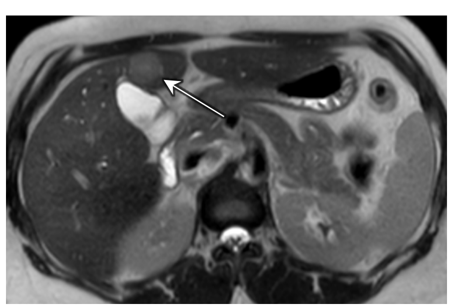
Mild-moderate T2 hyperintensity is present if:

- On T2-weighted sequences, the observation appears visually brighter than adjacent liver, but not brighter than non-iron-overloaded spleen. May be well defined or ill defined.



Example

T2W FSE



Signal is higher than adjacent liver,
but not higher than spleen

Mild-moderate T2 Hyperintensity

RADLEX ID: RID39468

If unsure

If unsure about mild-moderate T2 hyperintensity, do not characterize as mild-moderate T2 hyperintensity.

Pitfalls & practical considerations

While up to 86% of all HCCs and up to 53% of well-differentiated HCCs have T2 hyperintensity, T2 characteristics cannot reliably differentiate between small HCCs and benign nodules or between HCC and non-HCC malignancies.

T2 hyperintensity has limited sensitivity for HCC for small HCC. Its absence does not exclude HCC.

Fat-suppressed T2W imaging may cause errors in characterizing this feature:

- It may cause true T2 hyperintensity to be missed if the observation is steatotic.
- It may cause the false perception of T2 hyperintensity if the liver is steatotic.

Hepatic iron overload may cause errors in characterizing this feature :

- It may cause the false perception of T2 hyperintensity if the liver is very dark due to iron overload.

The visibility of this feature depends on the choice of pulse sequence and acquisition parameters. In general, it is seen more clearly on

- FSE than SSFE images and
- Moderately T2W (TE ~ 100 ms) than heavily T2W (TE ~ 200 ms) images

Although hemangiomas in the non-cirrhotic liver tend to be markedly T2 hyperintense, hemangiomas in the cirrhotic liver may become fibrotic (fibrosing or sclerosing hemangiomas) and can appear mildly-moderately T2 hyperintense. See page 16-49 and Chapter 15, page 6.

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Mild-moderate T2 Hyperintensity

RADLEX ID: RID39468

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Mild-moderate T2 Hyperintensity

RADLEX ID: RID39468

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Iron Sparing in Solid Mass

RADLEX ID: RID39465

Definition

Paucity of iron in solid mass relative to iron-overloaded liver or in inner nodule relative to outer siderotic nodule.

Synonyms

Lesional iron sparing, iron resistance

Terminology

Not applicable

Applicable modalities

MRI

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular.

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then iron sparing in solid mass causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, iron sparing in solid mass cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

Biological basis

Iron sparing suggests clonal expansion of high-grade dysplastic or malignant cells with iron “resistance” and is associated with dedifferentiation of regenerative and dysplastic nodules.

Thus, the degree of iron accumulation within hepatocellular nodules decreased from dysplastic nodules, to early HCC, to small progressed HCC, to large progressed HCC.

Iron Sparing in Solid Mass

RADLEX ID: RID39465

Summary of evidence

The incremental impact on diagnostic performance of iron sparing in a solid mass in combination with major features is not known.

In patients with cirrhosis and background liver iron overload, 98% of iron-sparing nodules are HCCs, and 2% are dysplastic nodules.

In patients with hemochromatosis, 67% of iron-sparing nodules are HCCs.

In patients with hemochromatosis and iron-sparing nodules on initial liver biopsy, 50% develop HCC (mean follow-up, 7 years), compared with 8% in the control group without such nodules.

Characterization

On MRI:

Characterize on dual-echo gradient-echo or T2W images. If obtained, can also characterize on R2* (=1/T2*) maps.

Iron sparing in solid mass is present if:

- The observation is a solid mass

  AND

- The liver (or outer nodule) is iron overloaded as evidenced by unequivocal signal loss on second echo compared to first echo **OR** abnormally low signal intensity on T2W images **OR** abnormally high R2* value on R2* maps

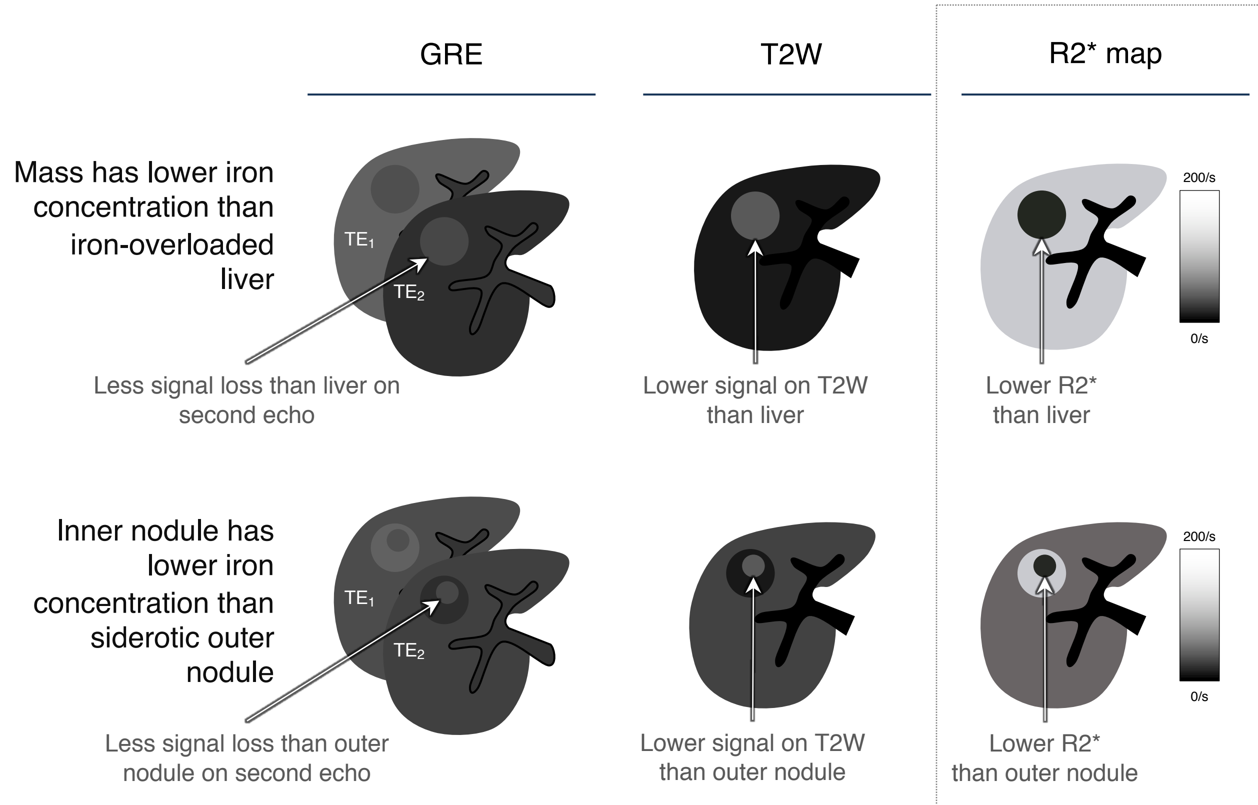
  AND

- The observation (or inner nodule) is less iron overloaded or non-iron overloaded (less or no signal loss on dual-echo, higher signal on T2W, lower or no R2* elevation).

Iron Sparing in Solid Mass

RADLEX ID: RID39465

Characterization (Cont'd)



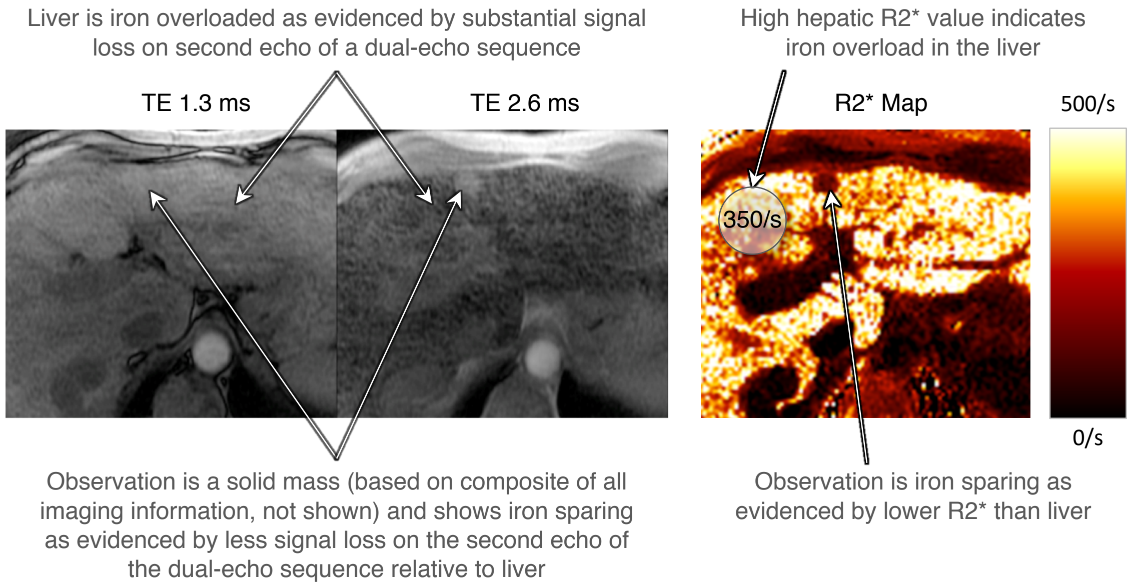
If obtained
(R2* maps are optional;
they are **not required** by LI-RADS)

Iron Sparing in Solid Mass

RADLEX ID: RID39465

Characterization

MRI example



Iron Sparing in Solid Mass

RADLEX ID: RID39465

If unsure

If unsure about iron sparing in solid mass, do not characterize as iron sparing in solid mass.

Pitfalls & practical considerations

Applies only to solid masses (see *Chapter 7, page 5*).

- Do not apply to nonsolid lesions like cysts or hemangiomas.
- Multiplanar images (source or reformatted) may help determine whether the observation is a mass.

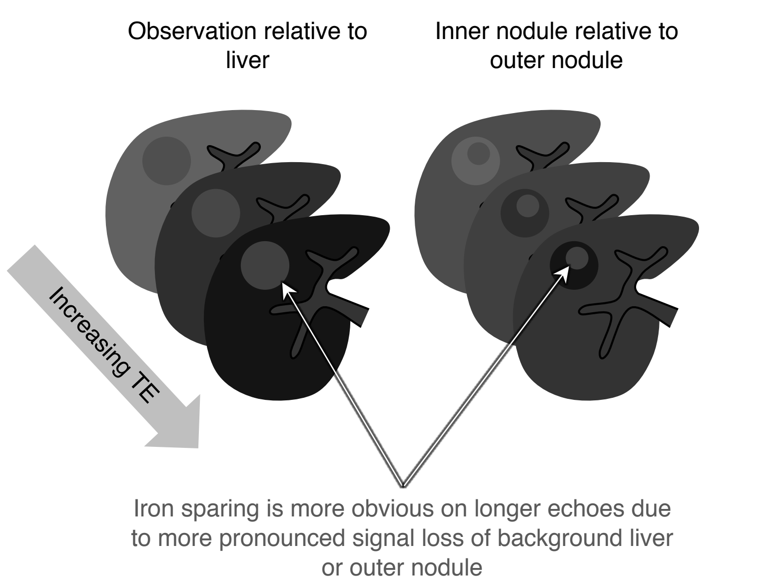
Any benign nonhepatocellular mass (e.g., nodular or confluent fibrosis) will contain less iron than surrounding iron-overloaded liver.

- Do not apply iron sparing as an ancillary feature favoring malignancy if the lesion is thought to be one of these benign entities.

Iron sparing is not specific for HCC and can be seen with non-HCC malignancies and some dysplastic nodules.

Iron sparing may be more visible on images with greater echo times due to more pronounced signal loss of background liver (or outer nodule).

Iron sparing is more obvious with greater echo times



Iron Sparing in Solid Mass

RADLEX ID: RID39465

Reference

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Transitional Phase Hypointensity

RADLEX ID: N/A

Definition

An observation with signal intensity in the transitional phase (TP) that is unequivocally lower in whole or in part than that of the surrounding liver.

Synonyms

Transitional phase hypoenhancement

Terminology

TP hypointensity is the preferred term as it is descriptive, unambiguous, and frequently used in the literature.

Applicable modalities

MRI with gadoxetate

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then transitional phase hypointensity causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, transitional phase hypointensity cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: if the transitional phase hypointensity has a targetoid morphology, the imaging feature should be characterized as targetoid transitional phase appearance (a LR-M feature) and the observation should be categorized LR-M. See page 16-227.

Transitional Phase Hypointensity

RADLEX ID: N/A

Biological basis

After injection of extracellular agents, the liver usually reaches peak enhancement in the portal venous phase, after which liver enhancement gradually declines as the agent is cleared from the extracellular space by renal excretion.

After injection of gadoxetate, by comparison, the hepatic parenchyma continues to enhance progressively after the portal venous phase due to uptake of the agent by hepatocytes. For this reason, relative hypointensity of an observation in the transitional phase is nonspecific: it may reflect rapid drainage of contrast material (i.e., "washout"), reduced uptake of gadoxetate compared to liver, or both.

Although "washout" is a major feature of HCC, reduced uptake is not. It can occur in dysplastic nodules and HCCs (dysfunctional hepatocytes) or in nonhepatocellular lesions (absence of hepatocytes). Given this uncertainty, transitional phase hypointensity does not have the same diagnostic significance as "washout" and does not constitute a major feature.

Summary of evidence:

TP hypointensity is an ancillary feature favoring malignancy

- TP hypointensity is reported in 47%–65% of HCCs.
- In patients at risk for HCC, the sensitivity and specificity of TP hypointensity for differentiating benign from premalignant or malignant lesions is unknown.
- Nevertheless, TP hypointensity is an independent predictor of HCC in lesions ≤ 3cm.

TP hypointensity does not qualify as "washout"

- In single-center studies using gadoxetate-enhanced MRI: the combination of nonrim APHE + portal venous washout or transitional phase hypointensity has lower specificity for HCC than the combination of nonrim APHE + portal venous "washout":

	Specificity for HCC of	
	APHE + PVP "washout"	APHE + PVP washout **OR** TP hypointensity
Joo 2015	98%	86%
Kim 2016	93%	79%
Choi 2017	100%	95%

Transitional Phase Hypointensity

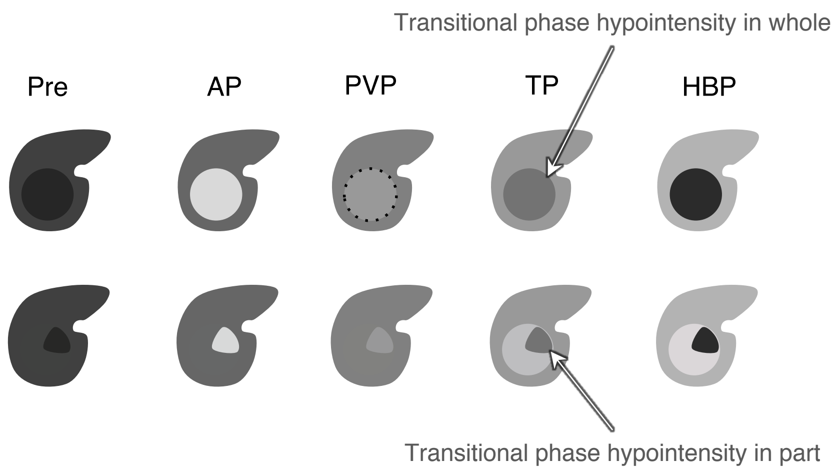
RADLEX ID: N/A

Characterization

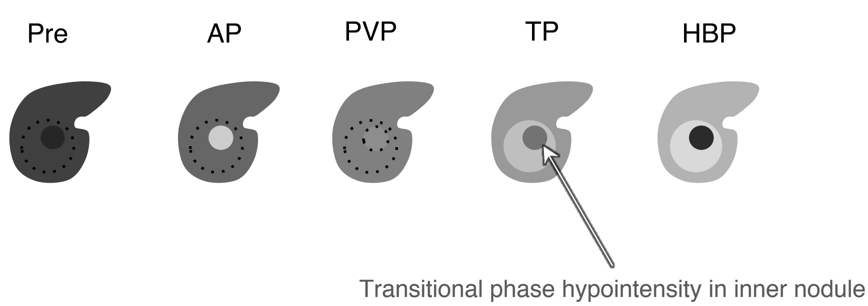
Characterize on transitional phase images, typically acquired 2-5 minutes after gadoxetate administration.

Transitional phase hypointensity is present if:

- The observation unequivocally has lower signal in whole or in part than liver.



- May manifest as inner hypointense nodule within non-hypointense outer nodule:



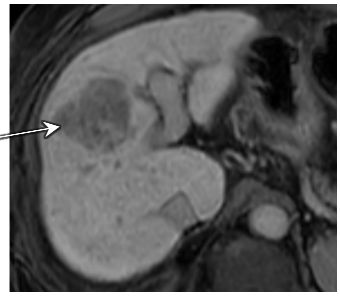
Transitional Phase Hypointensity

RADLEX ID: N/A

Example

5 min delayed TP

Low signal relative to background liver



If unsure

If unsure about TP hypointensity, do not characterize as TP hypointensity.

Pitfalls & practical considerations

The transitional phase typically occurs 2-5 minutes after injection but may extend up to 10 min after gadoxetate injection depending on liver function. Operationally, the transitional phase is defined as the period in which the intrahepatic vessels have about the same intensity as background liver. See *Chapter 13*.

TP hypointensity is not equivalent to “washout”

- “Washout” should be assessed on postarterial extracellular phase:
  - Portal venous phase if using gadoxetate
  - Portal venous or delayed phase if using extracellular agent or gadobenate

TP hypointensity is not specific for HCC and can be seen in

- hemangiomas
- non-HCC malignancies
- some dysplastic nodules
- siderotic nodules
- nodular or confluent fibrosis
- some cases of focal fat deposition
- some perfusion alterations

TP hypointensity usually occurs in conjunction with hepatobiliary phase hypointensity. Therefore, most observations with TP hypointensity also have hepatobiliary phase hypointensity. Nevertheless, at least one study showed that TP hypointensity is an independent predictor of HCC (see *page 16-296*).

Transitional Phase Hypointensity

RADLEX ID: N/A

References

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Rhee H, Kim MJ, Park YN, Choi JS, Kim KS. Gadoxetic acid-enhanced MRI findings of early hepatocellular carcinoma as defined by new histologic criteria. J Magn Reson Imaging. 2012;35(2):393-8.

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Hepatobiliary Phase Hypointensity

RADLEX ID: RID49813

Definition

Intensity in the hepatobiliary phase (HBP) that is unequivocally lower in whole or in part than that of the surrounding liver.

Synonyms

Hepatobiliary phase hypoenhancement, hepatobiliary phase “defect”

Terminology

HBP hypointensity is the preferred term as it is descriptive, unambiguous, and frequently used in the literature.

Applicable modalities

MRI with gadoxetate

Type of feature

Ancillary feature favoring malignancy in general, not HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then hepatobiliary phase hypointensity causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, hepatobiliary phase hypointensity cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: if the hepatobiliary phase hypointensity has a targetoid morphology, the imaging feature should be characterized as targetoid hepatbiliary phase appearance (a LR-M feature) and the observation should be categorized LR-M. See *page 16-227*.

Hepatobiliary Phase Hypointensity

RADLEX ID: RID49813

Biological basis

The degree of gadoxetate uptake by a given lesion depends on the expression and activity of molecular transporters known as OATPB1/B3, which in turn is determined by the underlying cytogenetic profile. In general, benign liver cells including hepatocytes found in regenerative nodules have relatively preserved OATPB1/B3 expression and activity levels. During hepatocarcinogenesis, OATPB1/B3 expression levels tend to decline, so dysplastic nodules and HCCs tend to have lower levels. See *Chapter 6*.

According to a recent systematic review:

- 98% of poorly differentiated HCCs are HBP hypointense.
- 86% of well or moderately differentiated HCCs ate HBP hypointense.
- 80% of high-grade dysplastic nodules are HBP hypointense.

HBP hypointensity is not specific for dysplastic nodules or HCC, however, and can be seen in non-HCC malignancies, hemangiomas, and other entities.

- 99-100% of iCCAs are HBP hypointense, with 39% being uniformly HBP hypointense, and 47-80% demonstrating a targetoid pattern.
- 100% of cHCC-CCAs are HBP hypointense, with 37% demonstrating a targetoid pattern.

Summary of evidence:

The addition of the HBP increases sensitivity by 5%–25% for the diagnosis of HCC since HBP hypointensity occurs earlier in hepatocarcinogenesis than hyperarterialization.

- HBP hypointensity increases sensitivity for small HCCs (< 2 cm) from 65 to 87% for all HBAs.
- HBP hypointensity increases sensitivity for small HCCs (< 2 cm) from 67 to 92% for gadoxetate.

HBP hypointensity is an independent predictor of early HCC, adjusting for APHE, restricted diffusion, and observation size.

For HBP-hypointense nodules without APHE:

- If followed, 28% (95% CI, 23-34%) will develop APHE. The cumulative incidence of APHE at 1, 2, and 3 years is 18% (95% CI, 9-27%), 25% (95% CI, 12-38%), and 30% (95% CI, 19-42%).
- If histologically sampled, 74% are HCCs and 10% are dysplastic nodules.

For HBP-hypointense nodules occult on all other sequences:

- If followed, the cumulative incidence of APHE at 1, 2, and 3 years is 14%, 26%, and 26%.

Conversely, for HBP-hyperintense nodules without APHE:

- If followed, only 1-4% will develop APHE.

Hepatobiliary Phase Hypointensity

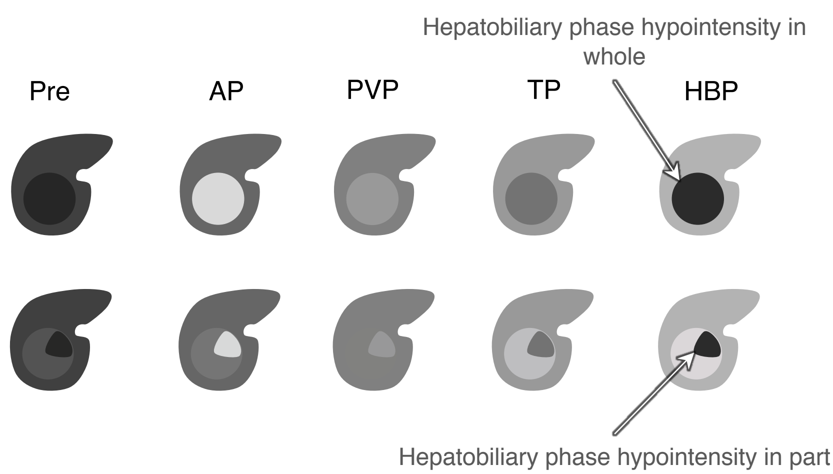
RADLEX ID: RID49813

Characterization

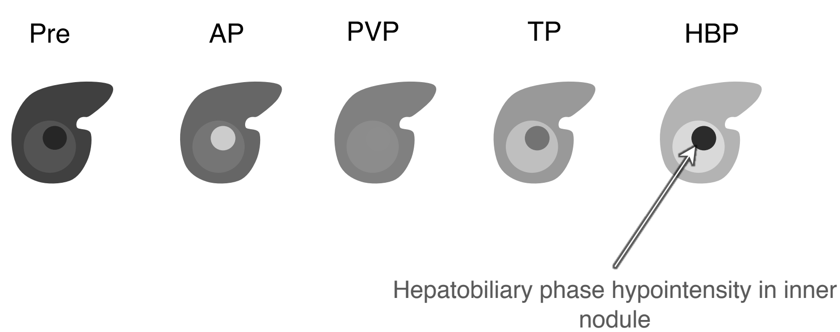
Characterize on hepatobiliary phase images, typically acquired 20 minutes after gadoxetate administration.

Hepatobiliary phase hypointensity is present if:

- The observation unequivocally has lower signal in whole or in part than liver.



- May manifest as inner hypointense nodule within non-hypointense outer nodule:

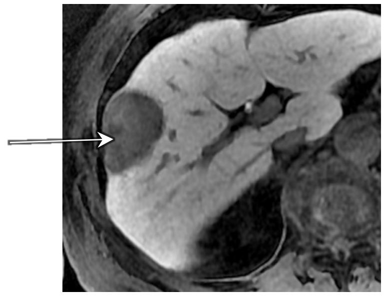


Hepatobiliary Phase Hypointensity

RADLEX ID: RID49813

Example

20 min delayed HBP



If unsure

If unsure about HBP hypointensity, do not characterize as HBP hypointensity.

Pitfalls & practical considerations

HBP hypointensity is not equivalent to “washout”.

Recognition of HBP hypointensity may be impaired if the HBP is suboptimal (see *Chapter 13*):

- Nodules that would normally appear hypointense relative to hyperenhancing parenchyma may appear isointense if liver enhancement is diminished.
- The incremental value of delaying the HBP in such cases is unknown but likely to be small.

HBP hypointensity is not specific for HCC and can be seen in:

- hemangiomas
- non-HCC malignancies
- some dysplastic nodules
- siderotic nodules
- nodular or confluent fibrosis
- some cases of focal fat deposition
- some perfusion alterations

Although iCCAs lack functional hepatocytes and therefore typically demonstrate HBP hypointensity, the pattern of hypointensity may suggest the correct diagnosis. In particular, iCCAs may manifest a targetoid appearance in the HBP, which is a feature of LR-M (see *page 16-227*) and should prompt LR-M categorization.

Hepatobiliary Phase Hypointensity

RADLEX ID: RID49813

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Hepatobiliary Phase Hypointensity

RADLEX ID: RID49813

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Hepatobiliary Phase Hypointensity

RADLEX ID: RID49813

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Ancillary Features Favoring HCC in Particular

Ancillary Imaging Features Favoring HCC in Particular & Imaging Modalities in Which They Are Visible

Ancillary features favoring HCC in particular

Feature	Definition	CT	MRI ECA	MRI HBA
Nonenhancing "capsule"	Capsule appearance not visible as an enhancing rim. See page 16-187 for definition of enhancing "capsule".	+	+	+
Nodule-in-nodule architecture	Presence of smaller inner nodule within and having different imaging features than larger outer nodule	+	+	+
Mosaic architecture	Presence of randomly distributed internal nodules or compartments, usually with different imaging features	+	+	+
Fat in mass, more than adjacent liver	Excess fat within a mass, in whole or in part, relative to adjacent liver	+ / –	+	+
Blood products in mass	Intralesional or perilesional hemorrhage in the absence of biopsy, trauma or intervention	+ / –	+	+

\+ usually evaluable – not evaluable + / – may or may not be evaluable

ECA = extracellular agent, *HBA* = hepatobiliary agent

Nonenhancing "Capsule"

RADLEX ID: N/A

Definition

Subtype of capsule appearance not visible as an enhancing rim.

Includes smooth, uniform, sharp nonenhancing border visible in PVP, DP, TP, or HBP.

Synonyms

There are no commonly used synonyms for this term (the literature has not consistently distinguished nonenhancing from enhancing "capsule").

Terminology

The terms nonenhancing capsule appearance and "capsule" (with quotation marks) are preferred over the term nonenhancing capsule. Rationale: the radiology-pathology correlation between nonenhancing "capsule" and true tumor capsule has not been established.

Applicable modalities

CT, MRI

Type of feature

Ancillary feature, favoring HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then nonenhancing "capsule" causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, nonenhancing "capsule" cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: nonenhancing "capsule" may cause the radiologist to question a prior LR-M category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Nonenhancing "Capsule"

RADLEX ID: N/A

Biological basis

See enhancing "capsule", page 16-191.

Summary of evidence

- The incremental impact on diagnostic performance of nonenhancing "capsule" in combination with major features is not known.
- Retrospective, single-center studies have shown that histologic capsules may be visible on unenhanced T1W, T2W, and HBP images.
- Presence of HBP hypointense rim, a type of nonenhancing "capsule", has 76-86% sensitivity for presence of a true histologic capsule.
- Up to 17% of all HCC have a hypointense rim in the HBP.
- Up to 75% of HCCs with HBP hyperintensity have a hypointense in the HBP.

Characterization

Characterize on

- Unenhanced CT: usually hypoattenuating
- AP, PVP, DP CT: must be hypoattenuating (i.e., "nonenhancing")
- Unenhanced T1W MRI: usually hypointense
- T2W or DW MRI: may be hypointense or hyperintense or bilayered
- Fat fraction or R2* maps (if obtained): must have no fat or R2* elevation
- AP, PVP, DP, TP, or HBP T1W MRI: must be hypointense (i.e., "nonenhancing")

Nonenhancing "capsule" is present if should be unequivocally thicker or more conspicuous than fibrotic tissue around background nodules

HBP T1W hyperintense rim does not count as nonenhancing "capsule".

Nonenhancing "Capsule"

RADLEX ID: N/A

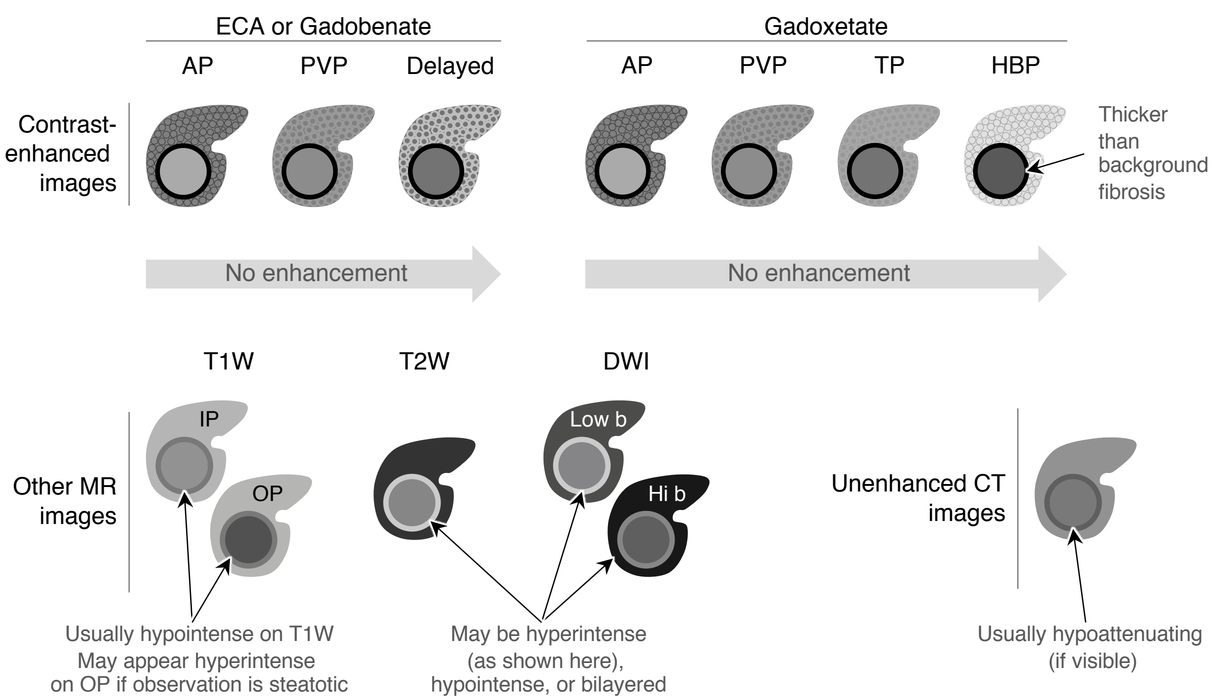
Characterization (Cont'd)

Nonhancing "capsule" is present if:

- There is a smooth, uniform, sharp border around most or all of an observation, unequivocally thicker or more conspicuous than fibrotic tissue around background nodules on one or more of the phases or sequences described above.

  AND

- The rim does not enhance. If the rim enhances progressively, it should be characterized as enhancing "capsule" (major feature of HCC), not as nonenhancing "capsule" (ancillary feature favoring malignancy).



The rim may be visible on only or a small number of phases or sequences. It does not need to be visible on every phase and sequence.

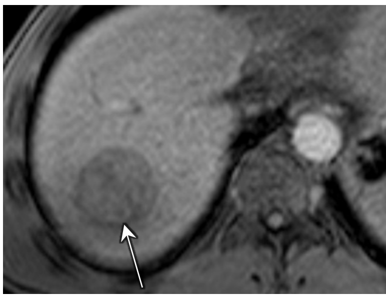
Nonenhancing “Capsule”

RADLEX ID: N/A

Characterization (Cont’d)

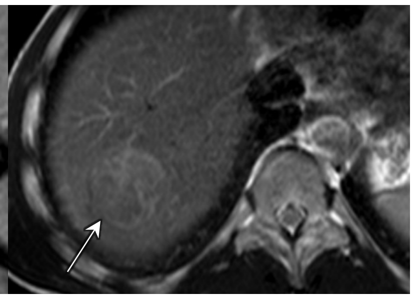
Example: MRI

T1 pre



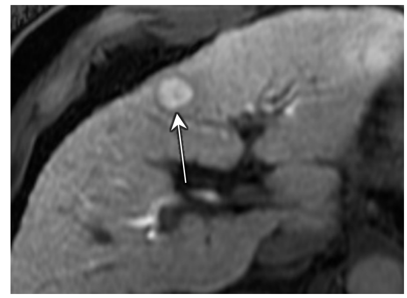
Peripheral rim of low signal on T1

T2



Bilayered (both high and low signal) peripheral rim on T2

HBP



Peripheral rim of low signal on HBP

If unsure

If unsure that ”capsule" is present, do not characterize as "capsule".

If unsure that "capsule" is enhancing or nonenhancing, characterize as nonenhancing "capsule".

Pitfalls & practical considerations

Nonenhancing “capsule” and targetoid appearance on DWI or HBP may overlap in imaging appearance. If a rim is uniformly thin, sharply demarcated, discrete structure, characterize as nonenhancing “capsule”. If a rim is thick, non-uniform, ill-defined, and non-discrete, characterize as targetoid appearance.

HBP hypointense “capsule” is usually imperceptible unless the observation is isointense or hyperintense relative to liver.

Nonenhancing “capsule” is depicted more clearly with MRI than CT (MRI has greater contrast resolution).

Similar to enhancing “capsule”, nonenhancing “capsule” suggests hepatocellular origin. If a LR-M observation has a either type of “capsule”, reevaluate. If re-evaluation confirms the presence of LR-M features as well as “capsule”, categorize as LR-M and report that the observation “may represent HCC with atypical features or cHCC-CCA”.

Nonenhancing "Capsule"

RADLEX ID: N/A

References

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Mosaic Architecture

RADLEX ID: RID39149

Definition

Presence of randomly distributed internal nodules or compartments, usually with different imaging features.

Synonyms

Mosaic pattern, mosaic appearance.

Terminology

Not applicable

Applicable modalities

CT, MRI

Type of feature

Ancillary feature, favoring HCC in particular.

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then mosaic architecture causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, mosaic architecture cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: mosaic architecture may cause the radiologist to question a prior LR-M category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Mosaic Architecture

RADLEX ID: RID39149

Biological basis

Mosaic architecture reflects the presence of inner nodules and compartments with varying degrees of dedifferentiation, fatty metamorphosis, necrosis, fibrosis, cystic degeneration, and hemorrhage. The various nodules are thought to represent clonal expansion of aberrant cells with different molecular and histological features, potentially ranging from dysplasia to poorly differentiated malignancy. The various nodules and compartments may differ in phenotypic and imaging features, including signal characteristics, diffusion, fat and iron content, dynamic enhancement pattern, and uptake of hepatobiliary agents.

Summary of evidence

The incremental impact on diagnostic performance of mosaic architecture in combination with major features is not known. Since mosaic architecture is more commonly seen in large tumors, the incremental impact on diagnosis of small tumors, which are more difficult to categorize, is likely to be modest.

Small retrospective observational case series in the 1990s reported that mosaic architecture was a common imaging feature in large HCCs > 5cm, being present in up to 65% of large HCCs.

Two recent studies examined the frequency of mosaic architecture using LI-RADS v2014 in HCC and non-HCC malignancies:

- One study (Fraum et al) reported mosaic architecture in
  - 4-23% in HCC, depending on the reader
  - 0% in non-HCC, regardless of the reader
- The other study (Horvat et al) reported mosaic architecture in
  - 37-65% in HCC, depending on the reader
  - 0-33% in non-HCC, depending on the reader
- The variable ranges for each tumor type reported by the two studies may reflect heterogeneity in patient populations and/or lack of reader reproducibility for characterizing mosaic architecture (inter-reader agreement for mosaic architecture in Horvat et al was low [kappa = 0.15-0.46])

Further research is needed to better understand mosaic architecture and improve the reader agreement for this feature in LI-RADS population.

Mosaic Architecture

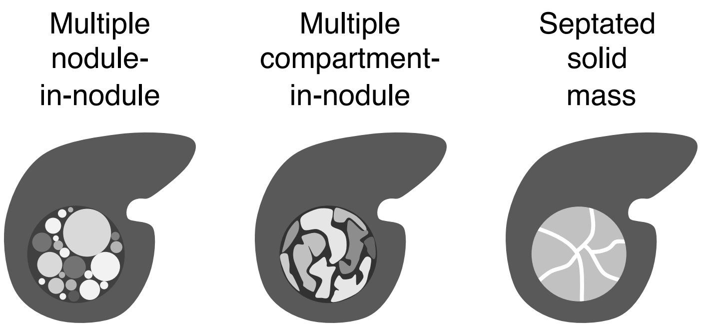
RADLEX ID: RID39149

Characterization

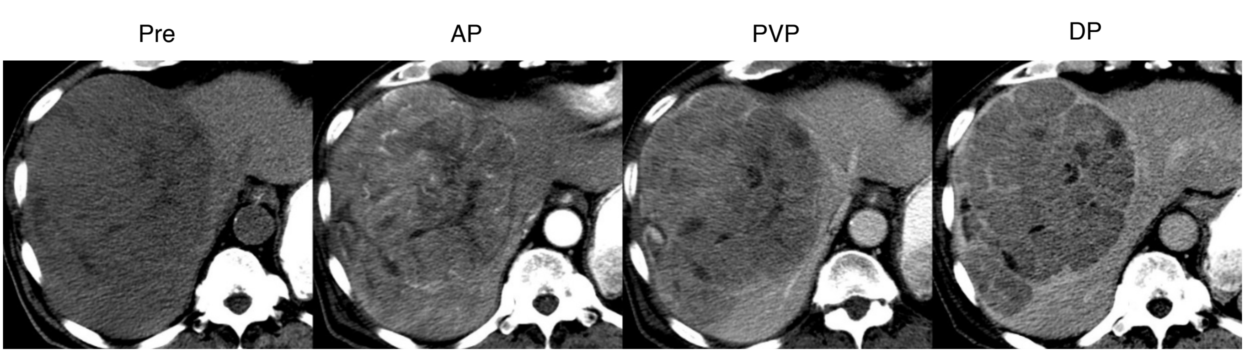
Characterize on any CT or MR images that depict the internal architecture of an observation.

Mosaic architecture is present if any of the following patterns are present:

- Multiple nodule-in-nodule appearance: multiple nodules of variable attenuation/intensity, size, and enhancement features randomly distributed within a larger mass
- Multiple compartment-in-nodule appearance: multiple compartments variable attenuation/intensity, size, and enhancement features, randomly distributed within a larger mass
- Septated solid mass: observation with internal irregular enhancing septa
- Combination of the above



Example: CT



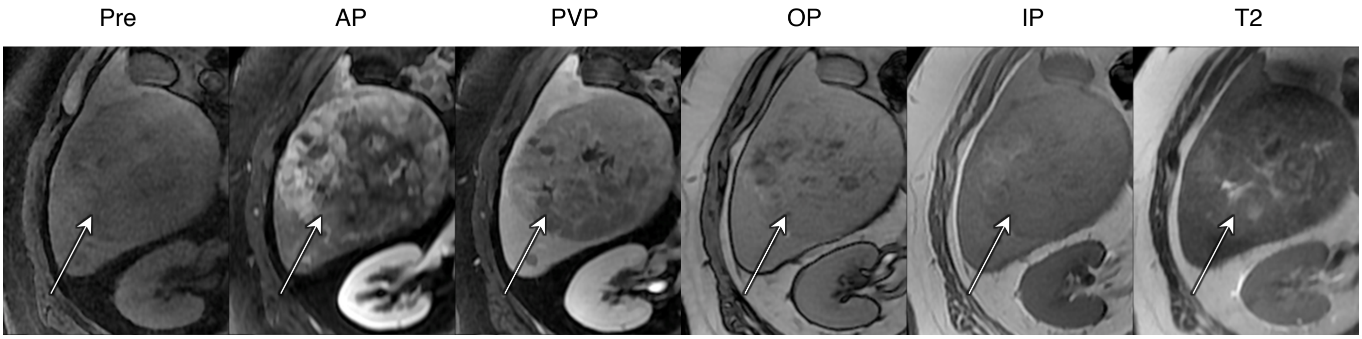
Multiple randomly distributed nodules and compartments with variable imaging features

Mosaic Architecture

RADLEX ID: RID39149

Characterization (Cont'd)

Example: MRI



Multiple randomly distributed nodules and compartments with variable imaging features

If unsure

If unsure about mosaic architecture, do not characterize as mosaic architecture.

Pitfalls & practical considerations

When measuring the size of a mosaic mass, the entire mass should be included in the measurement, not just the internal nodules or compartments.

An observation with mosaic architecture can be categorized as LR-5 if if any part demonstrates APHE, depending on other associated major features.

If no part demonstrates APHE, the observation cannot be categorized as LR-5.

Mosaic Architecture

RADLEX ID: RID39149

References

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Nodule-in-Nodule

RADLEX ID: RID39150

Definition

Presence of smaller inner nodule within and having different imaging features than larger outer nodule.

Synonyms

None

Terminology

While the term “mosaic architecture” may be applicable, “nodule-in-nodule” is preferred when there is a single nodule within a larger mass.

Applicable modalities

CT, MRI

Type of feature

Ancillary feature, favoring HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then nodule-in-nodule causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, nodule-in-nodule cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: nodule-in-nodule architecture may cause the radiologist to question a prior LR-M category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Nodule-in-Nodule

RADLEX ID: RID39150

Biological basis

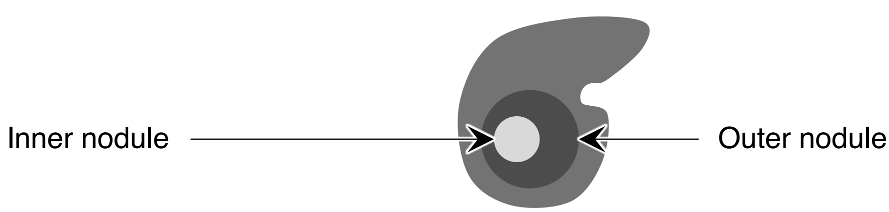
The inner nodule is thought to represent clonal expansion of cells more advanced in hepatocarcinogenesis pathway: e.g., the inner nodule is typically progressed HCC whereas the outer nodule is a dysplastic nodule or early HCC. As it is characteristic of hepatocarcinogenesis and does not occur with other malignant tumors such as cholangiocarcinomas, nodule-in-nodule appearance feature favors HCC in particular.

Summary of evidence

- The diagnostic performance of nodule-in-nodule architecture, as a standalone feature or in combination with major features is not known.
- Nodule-in-nodule can be seen in 2-36% of HCCs.
- Nodule-in-nodule has a wide range of application in practice. The inter-reader agreement is low in single-site studies (kappa = 0.36 - 0.41).

Characterization

An inner nodule is distinct from the outer nodule, both in morphololological appearance on unenhanced imaging and/or enhancement.



Features more characteristic of progressed HCC

- APHE
- “Washout”
- “Capsule”
- T2 hyperintensity
- Diffusion restriction
- Iron sparing
- Fat sparing
- HBP hypointensity

Features more characteristic of precursor nodule or early HCC

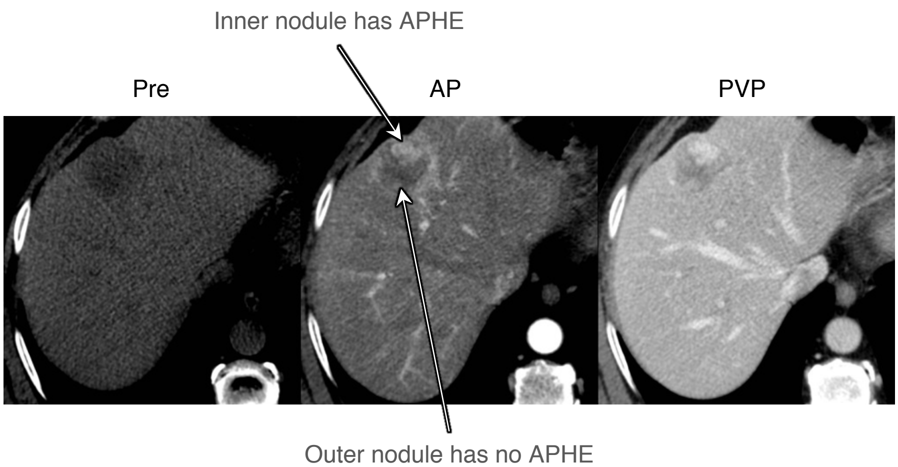
- No APHE
- No “Washout”
- No “Capsule”
- T2 hypointensity
- No diffusion restriction
- Iron accumulation
- Fat accumulation
- HBP isointensity

Nodule-in-Nodule

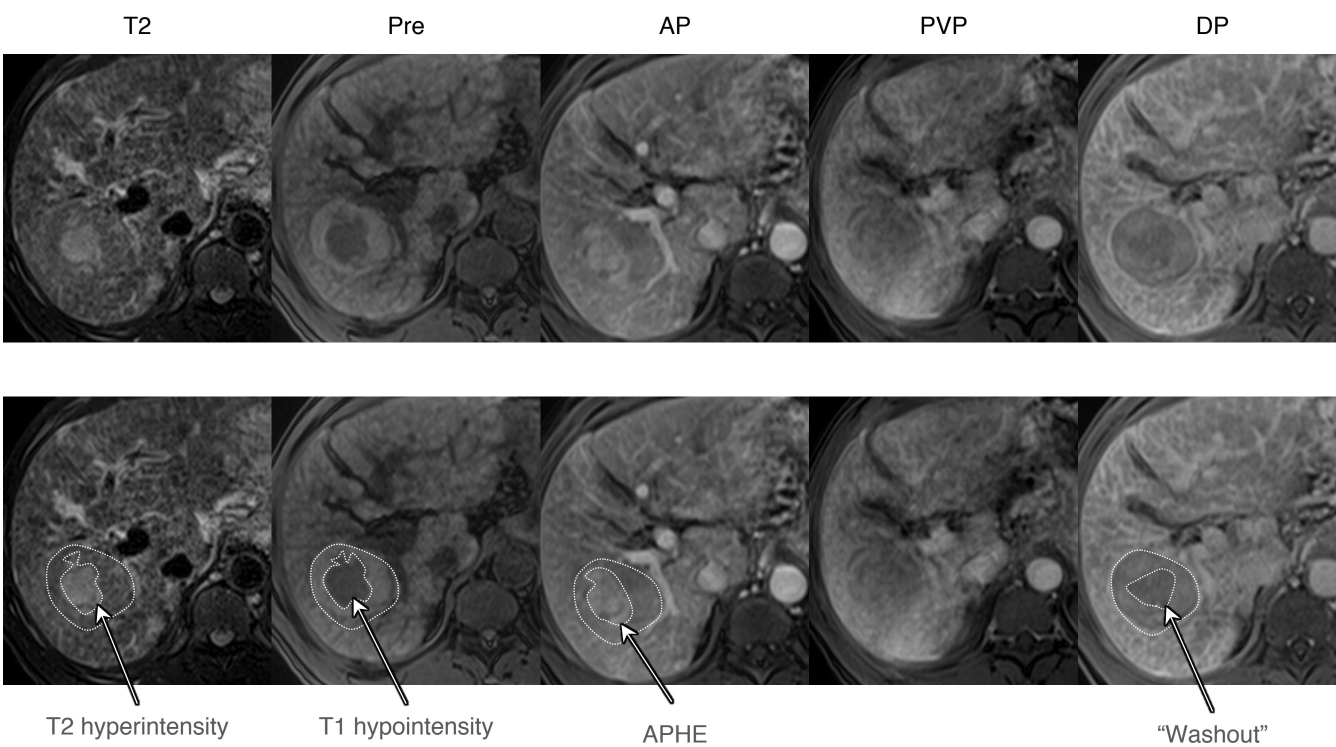
RADLEX ID: RID39150

Characterization (Cont'd)

Example: CT



Example: MRI



Inner nodule has more aggressive features than outer nodule

Nodule-in-Nodule

RADLEX ID: RID39150

If unsure

If unsure about nodule-in-nodule, do not characterize as nodule-in-nodule.

Pitfalls & practical considerations

When measuring the size of a nodule-in-nodule observation, the entire observation should be included in the measurement, not just the inner nodule.

An observation with nodule-in-nodule architecture can be categorized as LR-5 category if either the inner nodule or outer demonstrates APHE, depending on size and other associated major features.

If neither the inner nor the outer nodule demonstrates APHE, the observation cannot be categorized as LR-5.

Emerging data suggests that nodule-in-nodule may be seen in minority of non-HCC malignancies.

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Fat in Mass, More than Liver

RADLEX ID: RID39463

Definition

Increased fat within an observation, in whole or in part, relative to background liver.

Synonyms

Steatotic nodule, intralesional fat, fatty lesion, fat deposition, fatty metamorphosis, and intralesional fatty metaplasia.

Terminology

The descriptive term “fat in mass” is preferred over the synonyms above. Rationale: more than one mechanism may lead to fat accumulation. Thus, a descriptive term is preferred over a mechanistic term.

Applicable modalities

CT (with caution), MRI

Type of feature

Ancillary feature, favoring HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then fat in mass, more than liver causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, fat in mass, more than liver, cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: fat in mass may cause the radiologist to question a prior LR-M category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Fat in Mass, More than Liver

RADLEX ID: RID39463

Biological Basis

Intralesional fat in HCC may be a result of clonal expansion of dysplastic hepatocytes exhibiting an anomalous fat metabolism. Additionally, the switch of the dominant blood supply from portal venous to hepatic arterial during hepatocarcinogenesis may result in the metabolic disturbances which lead to accumulation of fat in mass more than liver.

Fat in mass favors HCC in particular as it occurs in lesions of hepatocellular origin (e.g. dysplastic nodules, early HCC, and some progressed HCC). Although some hepatocholangiocarcinomas may contain fat, this feature is rare in pure cholangiocarcinomas.

Other liver masses (e.g. adenoma, angiomyolipoma, teratoma, or metastases from liposarcoma or renal cell carcinoma) may also contain fat but are exceptionally rare in cirrhotic livers.

Summary of evidence

Fat content can be seen in 16-18% of HCCs on imaging.

Intralesional fat is most frequent in small HCCs (< 1.5 cm) and the frequency decreases with increasing size.

Pathology literature: up to 40% of early HCCs contain fat at histology. The percentage of dysplastic nodules and early HCCs showing fat at imaging is unknown.

The incremental contribution of fat in mass, more than liver to overall diagnostic performance is modest because

- fat in mass cannot reliably distinguish early HCCs from high-grade dysplastic nodules
- in progressed HCCs, fat in mass often occurs in conjunction with major features that by themselves permit LR-5 categorization

Fat in Mass, More than Liver

RADLEX ID: RID39463

Characterization

On MRI:

Characterize on out-of-phase (OP) compared to in-phase (IP) gradient-echo images.

If obtained, can also characterize on fat-only images, **OR** fat-fraction maps, **OR** fat-suppressed compared to otherwise similar non-fat-suppressed images (not shown in schematic below)

Fat in mass, more than liver is present if **ALL** of the following are met:

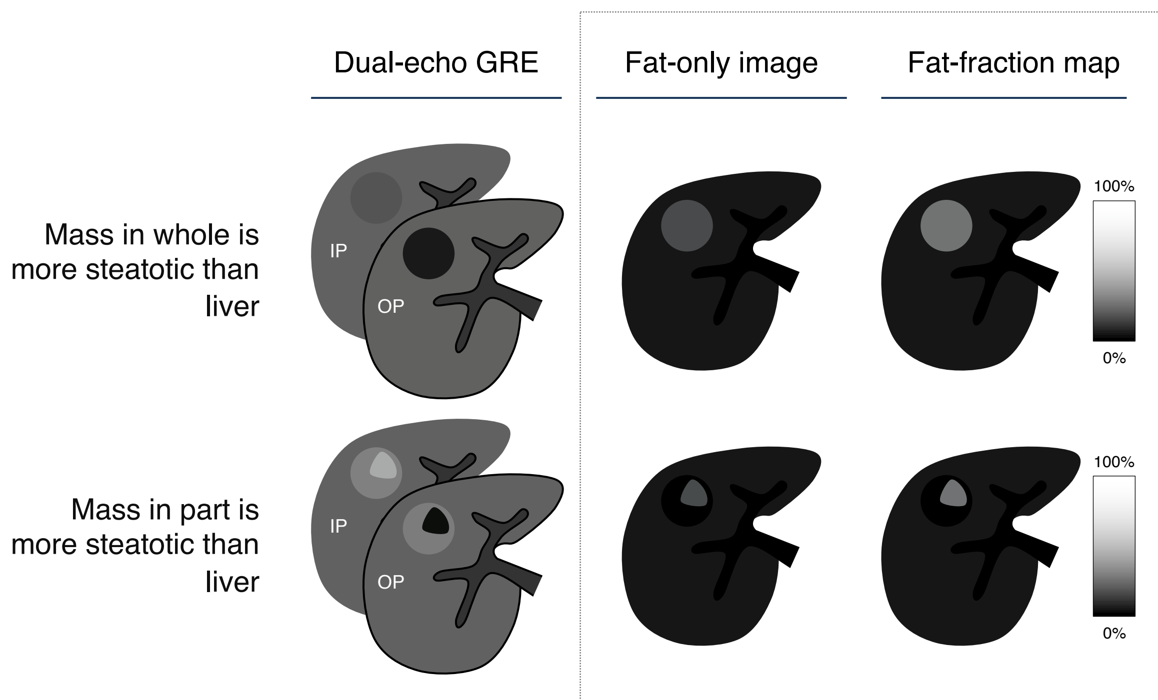
- The observation is a mass

AND

- The observation is steatotic in whole or in part as evidenced by unequivocal signal loss on OP compared to IP **OR** fat signal on fat-only images, **OR** positive fat fraction on fat-fraction maps, **OR** signal loss on fat-suppressed compared to non-fat-suppressed (not shown in schematic below)

AND

- The liver is less steatotic or nonsteatotic (less or no signal loss, lower or no fat signal, or lower or zero fat fraction on the corresponding images or maps)



If obtained
(these types of images are **not** required by LI-RADS)

Fat in Mass, More than Liver

RADLEX ID: RID39463

Characterization (Cont'd)

On CT:

With caution, this feature sometimes can be characterized on CT:

Fat in solid mass is present on CT if **ALL** of the following are met:

- The observation is a mass

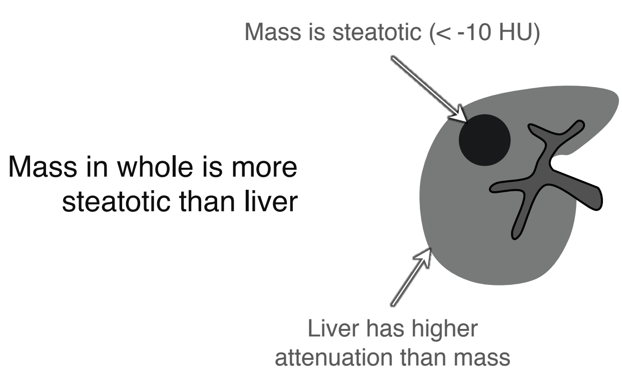
  AND

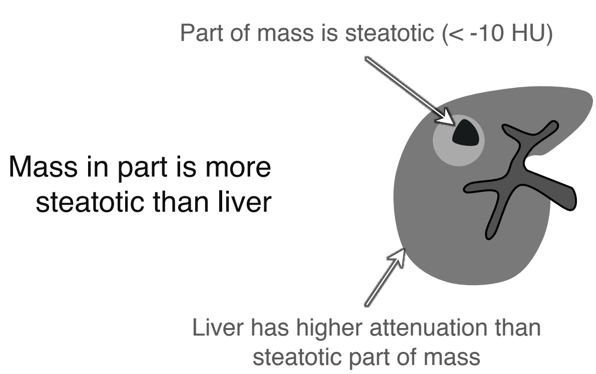
- The observation in whole or in part is unequivocally steatotic (attenuation < -10 HU)

  AND

- The liver is less steatotic or nonsteatotic (attenuation ≥ 40 HU).

CT



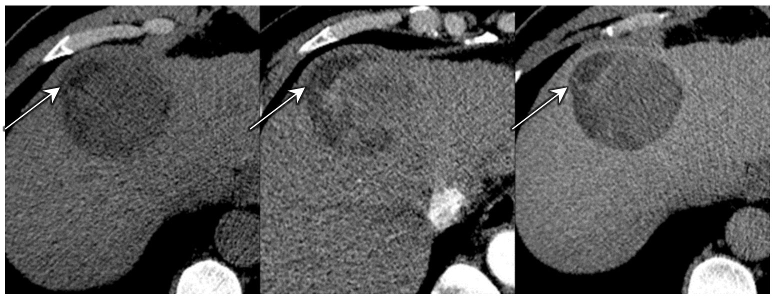


Fat in Mass, More than Liver

RADLEX ID: RID39463

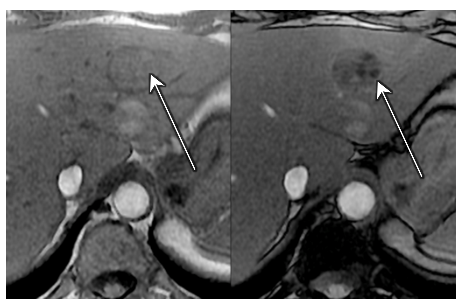
Characterization (Cont'd)

Example: CT



Focal area of fatty (-25 HU) attenuation within a mass relative to background liver

Example: MRI



Focal areas of signal loss on OP compared to IP within a mass relative to background liver

If unsure

If unsure about fat in mass, do not characterize as fat in mass.

Fat in Mass, More than Liver

RADLEX ID: RID39463

Pitfalls & practical considerations

Applies only to masses (see *Chapter 7, page 5*).

Fat in mass fat needs to be differentiated from hepatic fat deposition.

Imaging features that favor fat in mass over hepatic fat deposition:

- Observation is a mass (see *Chapter 7, page 5*).
- Enhancement differs from that of background liver in one or more postcontrast phases and the difference is not attributed to a perfusion alteration.

Perfusional alterations can be associated with hepatic fat deposition. Do not apply fat in mass as an ancillary feature favoring malignancy if you suspect the observation represents a perfusional alteration and not a mass.

MRI is more sensitive and specific for detection of fat in mass than CT. Apply this feature cautiously on CT. The attenuation threshold of -10 HU (see *page 16-326*) is arbitrary and intended to provide high specificity for the presence of fat.

Fatty attenuation may be seen after TACE with oil emulsions or after ethanol ablation.

Fat may be seen in some cHCC-CCAs.

Fat in mass is most frequent in small HCCs (< 1.5 cm). The frequency and homogeneity of intralesional fat decrease with increasing lesion size.

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Blood Products in Mass

RADLEX ID: RID43346

Definition

Intralesional hemorrhage in absence of biopsy, trauma, or intervention. Perilesional hemorrhage may or may not be present.

Synonyms

Hematoma, hemorrhage, methemoglobin, hemosiderin

Terminology

Not applicable

Applicable modalities

CT (with caution), MRI

Type of feature

Ancillary feature, favoring HCC in particular

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring benignity, then blood products in mass causes LR-1, LR-2, or LR-3 observations to be upgraded by *one* category to LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring malignancy, blood products in mass cannot be used to upgrade by two or more categories, cannot be used to upgrade to LR-5, and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: blood products in mass may cause the radiologist to question a prior LR-M category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Blood Products in Mass

RADLEX ID: RID43346

Biological basis

HCCs are hypervascular neoplasms prone to hemorrhage. Possible mechanisms include repetitive minor blunt trauma to superficial lesions, rapid elevations in intratumoral pressure secondary to thrombosis of draining veins, and rupture of fragile neoarteries within the tumor.

Other lesions prone to hemorrhage (e.g., adenomas and melanoma metastases) are exceedingly rare in cirrhosis. Importantly, HCC precursor nodules and other primary liver cancers associated with cirrhosis rarely hemorrhage. Thus, presence of blood products in mass favors HCC in particular.

Summary of evidence

The evidence supporting blood products in mass as an ancillary feature favoring malignancy is indirect and complicated by the use of variable terminology in the literature.

- 16-26% of HCCs have blood products on imaging:
  - 37/235 (16%) of HCCs had blood products on T2W MRI (defined as low signal intensity on T2W images).
  - 10/39 (26%) of HCCs in noncirrhotic liver had blood products on CT (defined as hyperattenuation on unenhanced images).
- Non-HCC malignancies uncommonly have have blood products on imaging:
  - Only 4/33 (12%) of cHCC-CCAs and 1/38 (3%) iCCAs have blood products on MRI (definition not provided).
- HCCs have blood products on imaging more frequently than iCCAs:
  - 11/22 (50%) of poorly differentiated HCCs but only 4/14 (29%) of iCCAs have blood products on MRI (defined as high signal intensity on T1 in phase GRE without signal drop on OP GRE and lack of contrast enhancement)
- Virtually no benign nodules have blood products on imaging.
  - Possible exception: Infarcted regenerative nodules may have blood products on pathology, unknown if they have blood products on imaging.

The incremental impact on diagnostic performance of blood products in mass in combination with major features is not known.

Blood Products in Mass

RADLEX ID: RID43346

Characterization

On MRI:

Characterize on unenhanced T1W, T2W, or T2*W images and compare to contrast-enhanced images.

Blood products in mass is present if **BOTH** of the following:

- There are amorphous or geographic areas of high signal on T1W images and either low (if chronic) or high (if acute or subacute) signal on T2W images. Due to T2* shortening, there may be signal loss on 2nd echo of a dual-gradient-echo sequence or high signal on R2* map.

  AND

- These areas do not enhance post contrast injection.

Older blood products (hemosiderin) have low signal intensity on T1W, T2W, and T2*W images.

On CT:

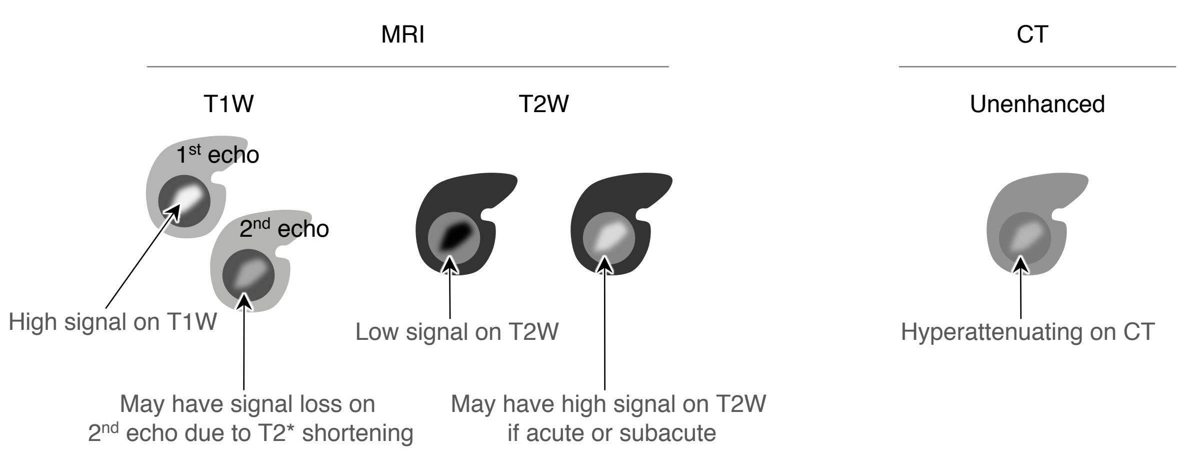
Characterize on unenhanced images, and compare to contrast-enhanced images.

Blood products in mass is present if if **BOTH** of the following:

- There are amorphous areas of hyperattenuation precontrast.

  AND

- These areas do not enhance after contrast injection.



Blood products do NOT enhance postcontrast (subtractions may help, see *Chapter 12, page 24*).

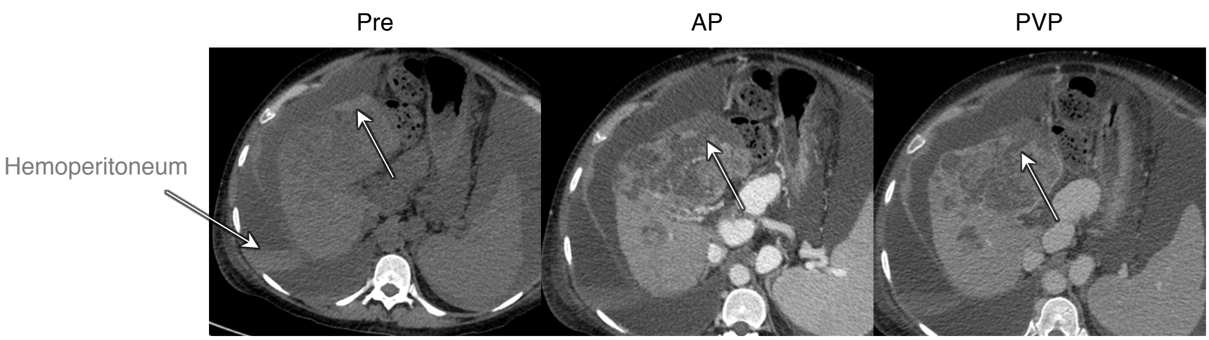
Blood Products in Mass

RADLEX ID: RID43346

Characterization (Cont'd)

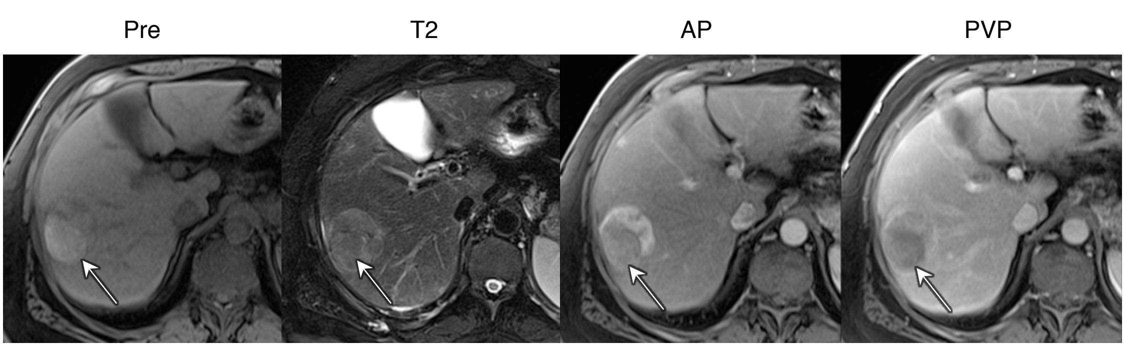
On either MRI or CT: there may be evidence of extrahepatic hemorrhage (e.g., hemoperitoneum).

Example: CT



Hyperdense, nonenhancing amorphous component consistent with acute/subacute hemorrhage

Example: MRI



Hyperintense on T1 | Mildly hyperintense on T2 | No enhancement | No enhancement

Nonenhancing intralesional subacute blood products

Blood Products in Mass

RADLEX ID: RID43346

If unsure

If unsure about blood products in mass, do not characterize as blood products in mass.

Pitfalls & practical considerations

Applies only to masses (see *Chapter 7, page 5*).

Size reduction should not be used as an ancillary feature favoring benignity in observations that reduce in size following resorption of acute bleed.

Blood products appear hyperattenuating on all phases at CT, potentially causing the misperception of enhancement.

Assessment of enhancement on MRI in a hemorrhagic HCC may benefit from subtraction imaging as intrinsic T1-hyperintensity of blood products may obscure APHE.

Imaging appearance depends on the acuity and size of blood products. Common imaging features of blood products include:

- High attenuation at unenhanced CT
- Variable signal on T1W images (often high if acute or subacute, low if chronic)
- Variable signal on T2W images (often low if acute, high if subacute, and low if chronic)
- Restricted diffusion
- Lack of enhancement

Emerging data suggests that susceptibility weighted imaging is more sensitive to blood products in HCC than T1- or T2-weighted imaging. LI-RADS does not currently recommend routine acquisition of susceptibility weighted imaging, however.

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Blood Products in Mass

RADLEX ID: RID43346

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Ancillary Features Favoring Benignity

LI-RADS® Ancillary Imaging Features Favoring Benignity & Imaging Modalities in Which They Are Visible

Ancillary features favoring benignity

Feature	Definition	CT	MRI ECA	MRI HBA
Size stability ≥ 2 years	No significant change in observation size measured on exams ≥ 2 years apart in absence of treatment	+	+	+
Size reduction	Unequivocal spontaneous decrease in size over time, not attributable to artifact, measurement error, technique differences, or resorption of blood products	+	+	+
Parallels blood pool enhancement	Temporal pattern in which enhancement eventually reaches and then matches that of blood pool	+	+	+
Undistorted vessels	Vessels traversing an observation without displacement, deformation, or other alteration	+	+	+
Iron in mass, more than liver	Excess iron in a mass relative to background liver	+ / –	+	+
Marked T2 hyperintensity	Intensity on T2WI markedly higher than liver and similar to bile ducts and other fluid-filled structures	–	+	+
Hepatobiliary phase isointensity	Intensity in hepatobiliary phase nearly identical to liver	–	–	+

+ usually evaluable – not evaluable + / – may or may not be evaluable

ECA = extracellular agent, *HBA* = hepatobiliary agent, *T2WI* = T2-weighted imaging

Size Stability ≥ 2 years

RADLEX ID: RID39448

Definition

No significant change in observation size measured on exams ≥ 2 years apart in absence of treatment.

Synonyms

Stable size, unchanged size, stable diameter, unchanged diameter

Terminology

Not applicable

Applicable modalities

CT, MRI

Type of feature

Ancillary feature that favors benignity

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring malignancy, then size stability causes LR-2, LR-3, LR-4 or LR-5 observations to be downgraded by *one* category to LR-1, LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring benignity, size stability ≥ 2 years cannot be used to downgrade by two or more categories and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: size stability ≥ 2 years may cause the radiologist to question a prior LR-M or LR-TIV category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Size Stability ≥ 2 years

RADLEX ID: RID39448

Biological basis

Premalignant and malignant neoplasms tend to grow. The average doubling time of dysplastic nodules and early HCCs is about 6 months. Therefore, in absence of treatment, some degree of measurable growth within 2 years is expected for most pre-malignant or premalignant lesions. Since such lesions are unlikely to remain stable for ≥ 2 years, size stability of this duration favors benignity.

Summary of evidence

The incremental impact on diagnostic performance of size stability ≥ 2 years in combination with major features is not known. Indirect evidence and biologic plausibility suggest that size stability ≥ 2 years favors benignity.

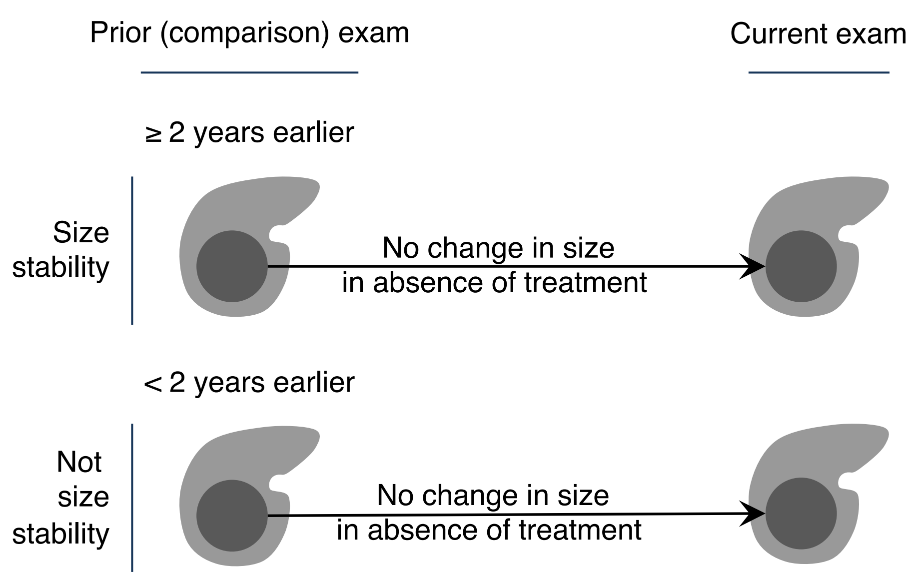
Characterization

Characterize on CT or MR exams performed at least two years apart. If possible, measure on images where observation margins are clearest and in same plane, sequence, phase.

Confirm absence of interim treatment.

Size stability is present if **EITHER**

- There is no measurable change in size **OR**
- A change in size is so small that the change is plausibly attributable to artifact, differences in imaging technique, or measurement error

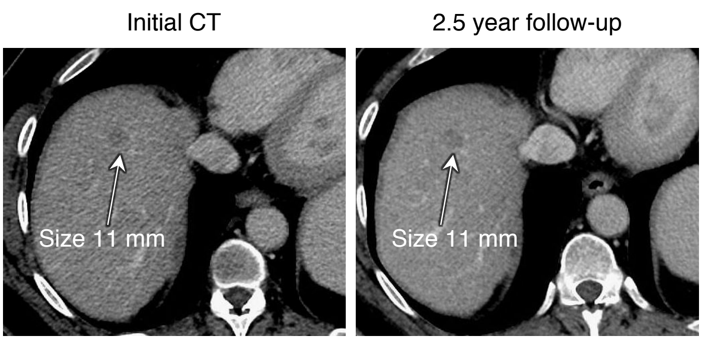


Size Stability ≥ 2 years

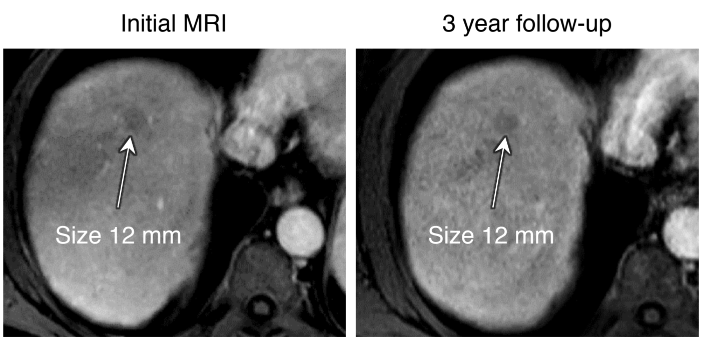
RADLEX ID: RID39448

Characterization (Cont'd)

Example: CT



Example: MR



If unsure

If unsure about size stability, do not characterize as size stability.

Pitfalls & practical considerations

- Size stability should not be used as an ancillary feature favoring benignity in observations that have undergone locoregional treatment.
- Size stability should be assessed on images obtained in the same plane and, if possible, acquired in the same phase or sequence.
- Some premalignant and malignant lesions grow slowly. Size stability favors benignity but does not confirm benignity with 100% certainty.

Size Stability ≥ 2 years

RADLEX ID: RID39448

References

Ebara M, Hatano R, Fukuda H, Yoshikawa M, Sugiura N, Saisho H. Natural course of small hepatocellular carcinoma with underlying cirrhosis. A study of 30 patients. Hepato-gastroenterology. 1998;45 Suppl 3:1214-20.

Jha RC, Zanello PA, Nguyen XM, Pehlivanova M, Johnson LB, Fishbein T, et al. Small hepatocellular carcinoma: MRI findings for predicting tumor growth rates. Acad Radiol. 2014;21(11):1455-64.

Yamagata M, Masaki T, Okudaira T, Imai Y, Shiina S, Shiratori Y, et al. Small hyperechoic nodules in chronic liver diseases include hepatocellular carcinomas with low cyclin D1 and Ki-67 expression. Hepatology. 1999;29(6):1722-9.

Size Reduction

RADLEX ID: N/A

Definition

Unequivocal spontaneous decrease in size over time, not attributable to artifact, measurement error, technique differences, or resorption of blood products.

Synonyms

Decreased size, shrinkage, regression

Terminology

The term size reduction is preferred since it is precise and clear.

Applicable modalities

CT, MRI (all contrast agents)

Type of feature

Ancillary feature that favors benignity

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring malignancy, then size stability causes LR-2, LR-3, LR-4 or LR-5 observations to be downgraded by *one* category to LR-1, LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring benignity, size reduction cannot be used to downgrade by two or more categories and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: size reduction may cause the radiologist to question a prior LR-M or LR-TIV category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Size Reduction

RADLEX ID: N/A

Biological basis

Spontaneous size decrease is exceeding rare in malignant lesions in absence of treatment or resorption of intratumoral hemorrhage. A published systematic review of English literature identified only 75 cases of spontaneous HCC regression reported between 1972 and 2012.

Proposed mechanisms include

- tumor ischemia and necrosis induced by rapid growth
- immune response against tumor cells, possibly triggered by an otherwise unrelated bacterial infection

The cause of regression is unknown in ~50% of cases.

Summary of evidence

The incremental impact on diagnostic performance of size reduction in combination with major features is not known. Indirect evidence and biologic plausibility suggest that size reduction favors benignity.

Size Reduction

RADLEX ID: N/A

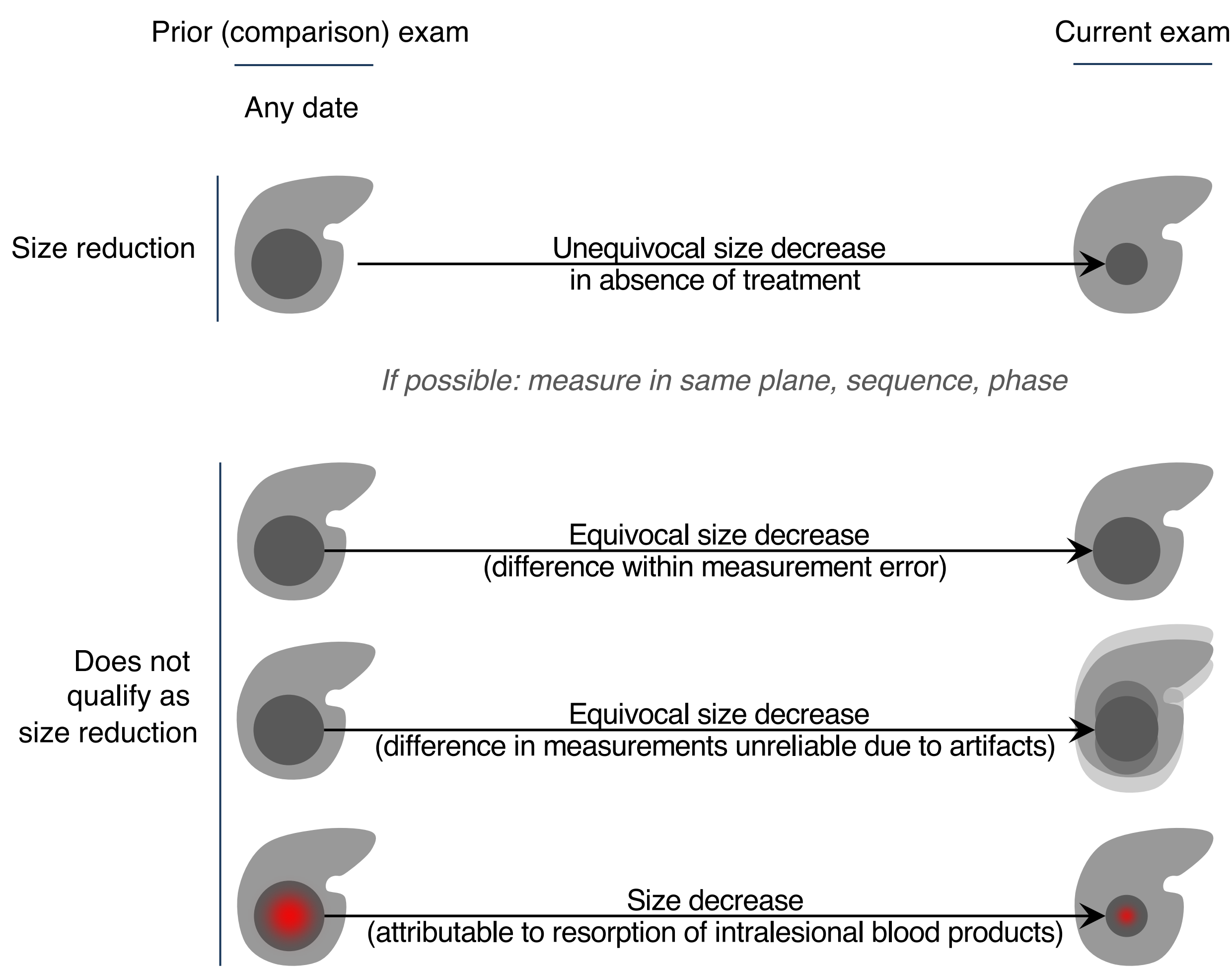
Characterization

Characterize on serial CT or MR exams performed on different dates. If possible, measure on images where observation margins are clearest and in same plane, sequence, phase.

Confirm absence of interim treatment.

Size reduction is present if **BOTH**:

- Observation is measurably smaller on later than earlier exam **AND**
- Reduction in size is not attributable to artifact, measurement error, technique differences, resorption of intralesional blood products, or interim treatment.



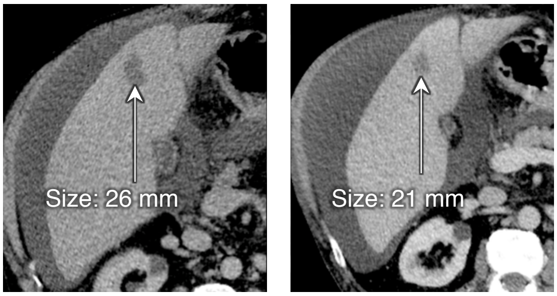
Size Reduction

RADLEX ID: N/A

Characterization (Cont'd)

Example: CT

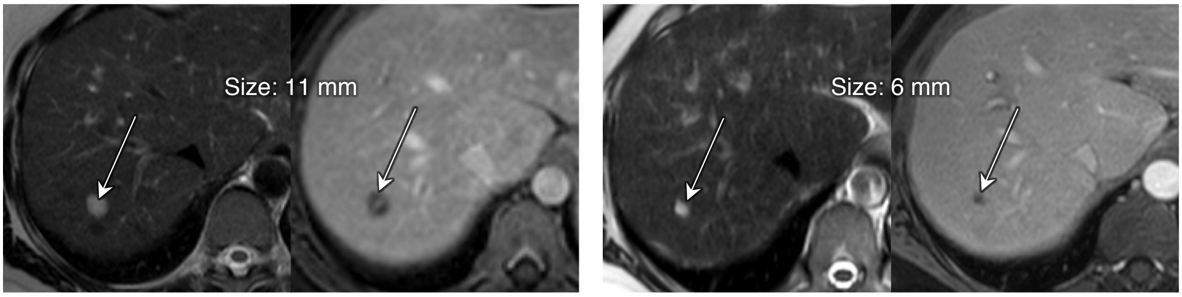
Initial CT | Follow-up CT 7 months later



Example: MRI

Initial MRI | Follow-up MRI 8 years later

T2 | PVP | T2 | PVP



If unsure

If unsure about size reduction, do not characterize as size reduction.

Size Reduction

RADLEX ID: N/A

Pitfalls & practical considerations

Size reduction should not be used as an ancillary feature favoring benignity in observations that become smaller due to resorption of blood products.

Size reduction should be assessed on images in the same plane and, if possible, acquired in the same phase or sequence.

There is no minimum reduction in size for application of this feature, rather the reduction in size should be unequivocal in judgment of the radiologist.

Need to confirm absence of interim treatment.

References

Huz JI, Melis M, Sarpel U. Spontaneous regression of hepatocellular carcinoma is most often associated with tumour hypoxia or a systemic inflammatory response. HPB (Oxford). 2012 Aug;14(8):500-5.

Parallels Blood Pool Enhancement

RADLEX ID: RID39472

Definition

Temporal pattern in which enhancement is similar to that of blood pool on all phases

Synonyms

Following signal/attenuation/brightness/enhancement of blood pool on all phases

Terminology

Not applicable

Applicable modalities

CT, MRI (all contrast agents)

Type of feature

Ancillary feature that favors benignity

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring malignancy, then parallels blood pool enhancement causes LR-2, LR-3, LR-4 or LR-5 observations to be downgraded by *one* category to LR-1, LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring benignity, parallels blood pool enhancement cannot be used to downgrade by two or more categories and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: parallels blood pool enhancement may cause the radiologist to question a prior LR-M category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category. In particular, the radiologist may wish to consider hemangioma or other benign vascular lesion.

Parallels Blood Pool Enhancement

RADLEX ID: RID39472

Biological basis

This temporal enhancement pattern suggests that the observation is composed mainly of vascular spaces filled with blood. This occurs in hemangiomas (which contain abundant vascular channels surrounded by loose fibromuscular stroma) and purely vascular lesions such as aneurysms, pseudo-aneurysms, and arteriovenous fistulas.

Summary of evidence

In a retrospective study comparing small hemangiomas and small (<3 cm) hypervascular malignant tumors:

- Enhancement similar to aortic enhancement was observed in the arterial phase in 19-32% of hemangiomas and 0-2% of malignant tumors.
- Enhancement similar to blood pool was observed in the PVP in 43-54% of hemangiomas and 4-14% of malignant tumors
- The sensitivity and specificity in differentiating hemangiomas vs small hypervascular malignant tumors were 47-53% and 95%, respectively.

The diagnostic performance of blood pool parallelism, in the absence of the characteristic morphologic pattern of a hemangioma, is not known.

Parallels Blood Pool Enhancement

RADLEX ID: RID39472

Characterization

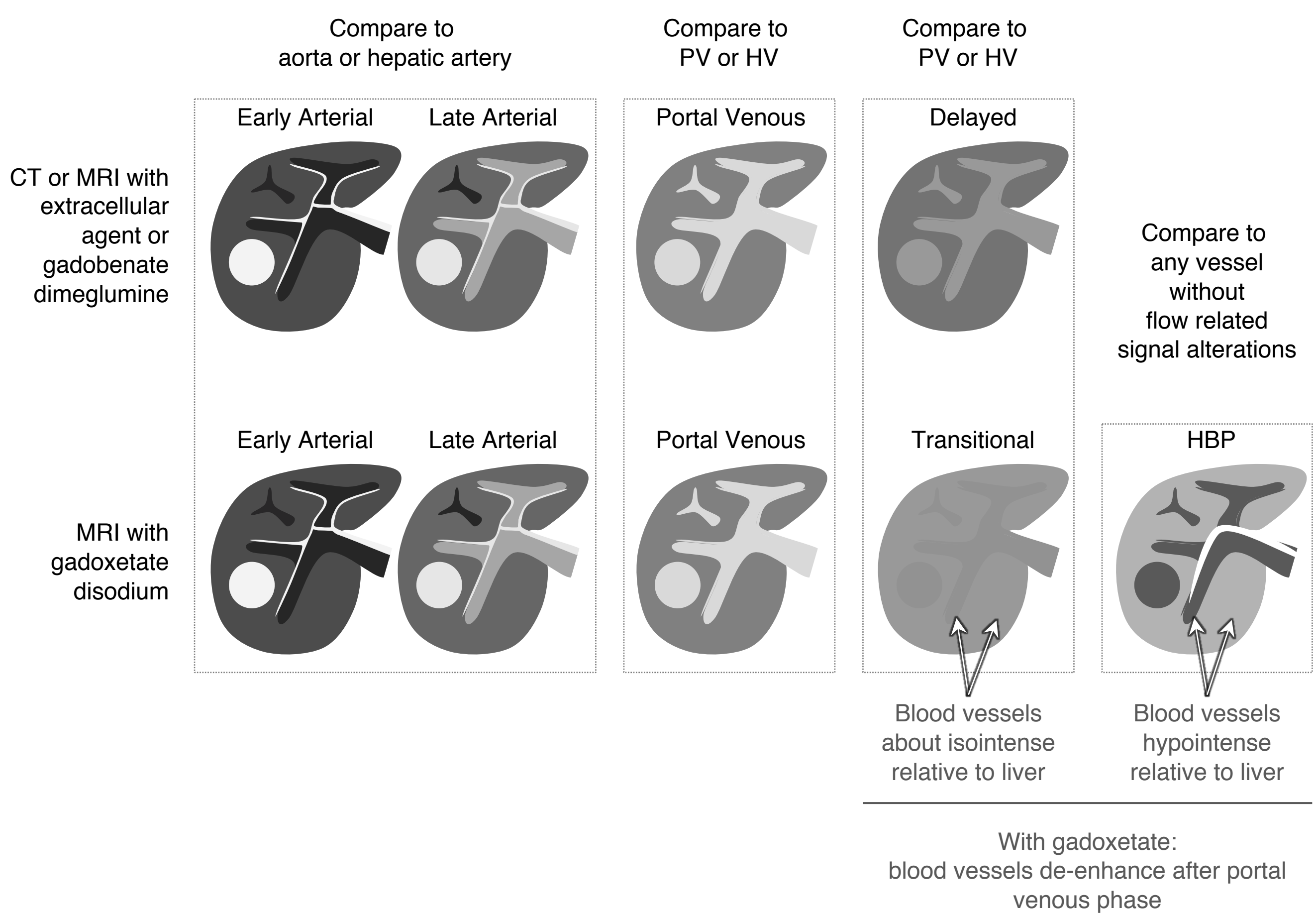
Characterize on multiphase CT or MR images by comparing the enhancing portion(s) of the observation to blood vessels representative of the blood pool in each phase.

In general, the following blood vessels are representative of the blood pool in each phase:

- Arterial phase: aorta or hepatic artery
- Portal venous phase: portal vein
- 2- to 5- minutes delayed phase/transitional phase: portal vein or hepatic vein
- Hepatobiliary phase (hepatobiliary agents only): any vessel with little or no flow-related signal alteration

Parallels blood pool enhancement is present if:

- Enhancement is similar to blood pool on every phase, using vessel(s) representative of the blood pool as comparators. Note that with gadoxetate the blood pool de-enhances after portal venous phase. Relative to liver, the blood pool becomes about isointense in transitional phase and hypointense in HBP.



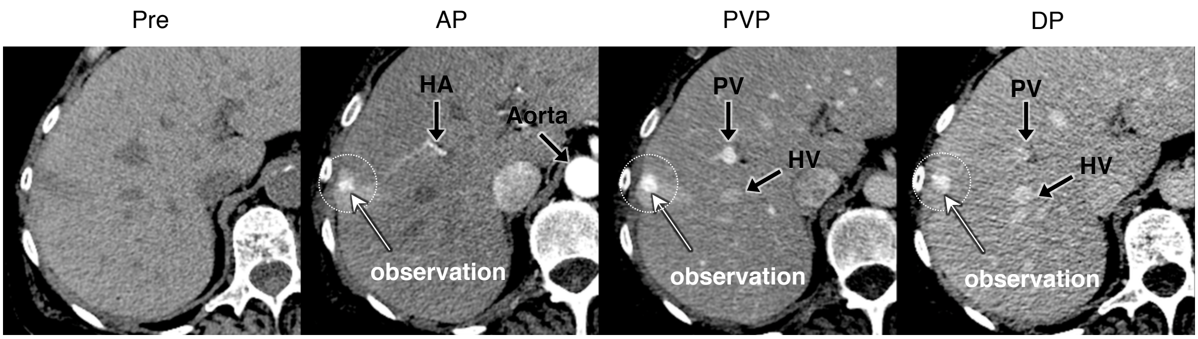
Parallels Blood Pool Enhancement

RADLEX ID: RID39472

Characterization (Cont'd)

Example: CT

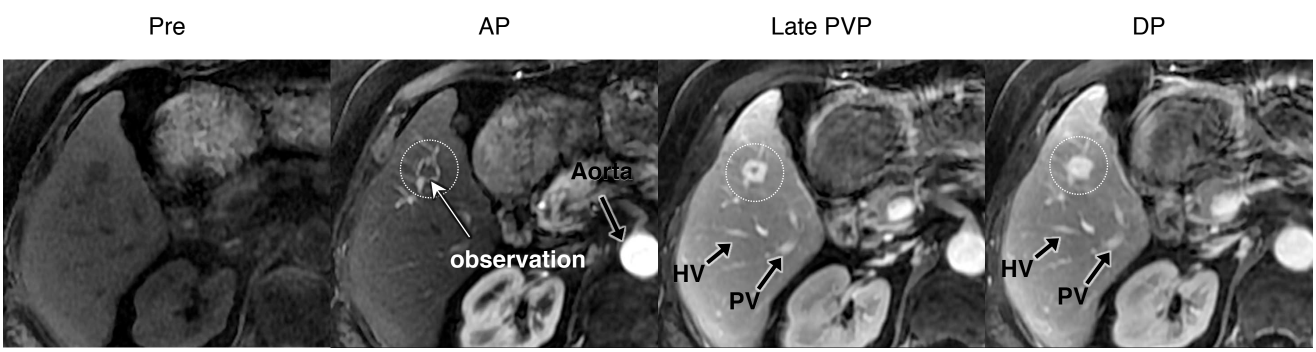
Internal enhancement of the observation is similar in density to the blood pool on all postcontrast phases



Compare to aorta and/or hepatic artery | Compare to PVP and/or HV | Compare to PVP and/or HV

Example: MRI

Internal enhancement of the observation is similar in intensity to the blood pool on all postcontrast phases



Compare to aorta and/or hepatic artery | Compare to PVP and/or HV | Compare to PVP and/or HV

Parallels Blood Pool Enhancement

RADLEX ID: RID39472

If unsure

If unsure about enhancement that parallels blood pool, do not characterize as parallels blood pool enhancement.

Pitfalls & practical considerations

- Since the liver has a dual blood supply and since the various vessels enhance at different times after injection, the blood vessel(s) representative of the blood pool depend on the phase.
- In general, the aorta and hepatic artery are representative of the blood pool in the AP and the portal vein and/or hepatic vein on subsequent phases. Due to variability in contrast dose and rate, acquisition timing, and patient physiology, however, these are not absolute rules. Radiologists should use their judgment in selecting the appropriate comparator vessels for each phase.
- Note that with gadoxetate the blood pool de-enhances after portal venous phase. Relative to liver, it becomes about isointense in TP and hypointense in HBP. The progressive darkening of the blood pool after the portal venous phase may cause diagnostic confusion.
- Enhancement that parallels blood pool is assessed subjectively. Quantitative criteria for this pattern have not been developed.
- Most observations with this pattern can be interpreted as definite or probable hemangiomas.
  - Use other features (i.e. homogeneous marked T2-hyperintensity and nodular peripheral enhancement pattern) to confirm the diagnosis of hemangioma.
  - Following gadoxetate injection, hemangiomas show hypointensity relative to surrounding parenchyma in the TP and HBP ("pseudo-washout") but still parallel blood pool enhancement. In a single-center retrospective study of gadoxetate-enhanced MRI, all hepatic hemangiomas matched the signal intensity of the portal veins on all postcontrast phases.
- Other observations with this pattern can be interpreted as definite or probable pseudo-aneurysms or arterio-venous fistulas based on the presence of direct vascular connections.
  - These lesions tend to appear markedly hypointense on motion-sensitive sequences (e.g., diffusion weighted imaging) due to high flow.
- Some observations with this pattern cannot be confidently diagnosed as definite or probable hemangiomas or vascular lesions due to small size or other factors. For such observations, this enhancement pattern is an ancillary feature favoring benignity.

Parallels Blood Pool Enhancement

RADLEX ID: RID39472

References

Brancatelli G, Federle MP, Blachar A, Grazioli L. Hemangioma in the cirrhotic liver: diagnosis and natural history. Radiology. 2001;219(1):69-74.

Kim B, Byun JH, Kim HJ, Won HJ, Kim SY, Shin YM, et al. Enhancement patterns and pseudo-washout of hepatic haemangiomas on gadoxetate disodium-enhanced liver MRI. Eur Radiol. 2016;26(1):191-8.

Kim T, Federle MP, Baron RL, Peterson MS, Kawamori Y. Discrimination of small hepatic hemangiomas from hypervascular malignant tumors smaller than 3 cm withthree-phase helical CT. Radiology. 2001 Jun;219(3):699-706.

Motosugi U, Ichikawa T, Onohara K, Sou H, Sano K, Muhi A, Araki T. Distinguishing hepatic metastasis from hemangioma using gadoxetic acid-enhanced magnetic resonance imaging. Invest Radiol. 2011 Jun;46(6):359-65.

Oto A, Kulkarni K, Nishikawa R, Baron RL. Contrast enhancement of hepatic hemangiomas on multiphase MDCT: Can we diagnose hepatic hemangiomas by comparing enhancement with blood pool? AJR. 2010 Aug;195(2):381-6.

Semelka RC, Brown ED, Ascher SM, Patt RH, Bagley AS, Li W, Edelman RR, ShoenutJP, Brown JJ. Hepatic hemangiomas: a multi-institutional study of appearance onT2-weighted and serial gadolinium-enhanced gradient-echo MR images. Radiology.1994 Aug;192(2):401-6.

Tamada T, Ito K, Yamamoto A, Sone T, Kanki A, Tanaka F, Higashi H. Hepatic hemangiomas: evaluation of enhancement patterns at dynamic MRI with gadoxetate disodium. AJR. 2011 Apr;196(4):824-30.

Yamashita Y, Ogata I, Urata J, Takahashi M. Cavernous hemangioma of the liver: pathologic correlation with dynamic CT findings. Radiology. 1997Apr;203(1):121-5.

Undistorted Vessels

RADLEX ID: RID39484

Definition

Vessels traversing an observation without displacement, deformation, or other alteration.

Synonyms

Lack of mass effect on vessels

Terminology

Not applicable

Applicable modalities

CT, MRI (all contrast agents)

Type of feature

Ancillary feature that favors benignity

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring malignancy, then undistorted vessels causes LR-2, LR-3, LR-4 or LR-5 observations to be downgraded by *one* category to LR-1, LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring benignity, undistorted vessels cannot be used to downgrade by two or more categories and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: undistorted vessels may cause the radiologist to question a prior LR-M or LR-TIV category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Biological basis

Neoplasms are space-occupying lesions and therefore are expected to displace and/or distort parenchyma and blood vessels. Perfusion alterations, areas of fat deposition, and hypertrophic pseudomasses are not true space-occupying processes and therefore do not distort adjacent or traversing vessels.

Undistorted Vessels

RADLEX ID: RID39484

Summary of evidence

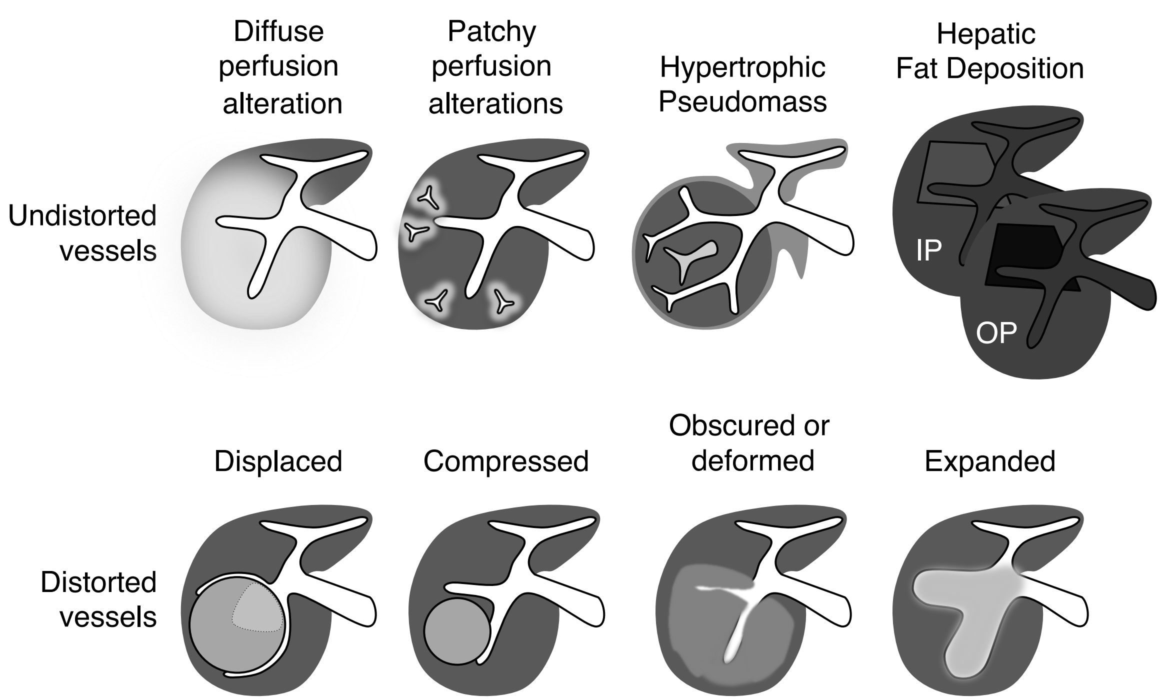
The incremental impact on diagnostic performance of undistorted vessels in combination with major features is not known. Indirect evidence and biologic plausibility suggest that undistorted vessels favor benignity.

Characterization

Characterize on any CT or MR images that depict the course of blood vessels adjacent to or traversing an observation. These are usually but not always contrast-enhanced images.

Undistorted vessels are present if:

- Vessels are visualized traversing an observation without displacement, compression, obscuration, deformation, or expansion.



Undistorted Vessels

RADLEX ID: RID39484

Characterization (Cont'd)

Example: CT

AP

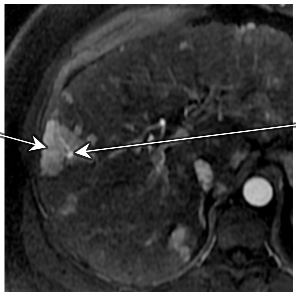
Hyperenhancing observation

Undistorted vessel

Example: MRI

AP

Hyperenhancing observation



Undistorted vessel

If unsure

If unsure about undistorted vessels, do not characterize as undistorted vessels.

Pitfalls & practical considerations

While undistorted vessels have not been described in expansile HCC, they may occur in diffuse HCC and other malignant neoplasms with infiltrative appearance (e.g., lymphoma, some metastases). Thus, undistorted vessels by themselves do not establish the diagnosis of benignity.

Multiplanar imaging (acquired or reconstructed) may help visualize the course of traversing vessels and increase the confidence for characterizing this feature as present or absent.

References

No references have been found.

Iron in Mass, More than Liver

RADLEX ID: N/A

Definition

Excess iron in an observation relative to background liver.

Synonyms

Siderotic nodule

Terminology

Not applicable

Applicable modalities

CT (with caution), MRI

Type of feature

Ancillary feature that favors benignity

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring malignancy, then iron in mass more than liver causes LR-2, LR-3, LR-4 or LR-5 observations to be downgraded by *one* category to LR-1, LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring benignity, iron in mass cannot be used to downgrade by two or more categories and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: iron in mass may cause the radiologist to question a prior LR-M or LR-TIV category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Iron in Mass, More than Liver

RADLEX ID: N/A

Biological basis

Accumulation of iron suggests clonal expansion of cells with iron avidity. The accumulation of iron is a well-recognized histological feature of low-grade dysplastic nodules. As hepatocarcinogenesis progresses, cells become “iron resistant” so that high-grade dysplastic nodules, early HCCs, and progressed HCCs rarely contain any stainable iron. Additionally, iron accumulation is not a known feature of iCCA or most non-HCC malignancies. Hence, presence of iron favors non-malignant etiology.

Summary of evidence

The incremental impact on diagnostic performance of iron in a mass in combination with major features is not known. Indirect evidence and biologic plausibility suggest that iron in a mass favors benignity.

Iron in Mass, More than Liver

RADLEX ID: N/A

Characterization

On MRI:

Characterize on dual-echo gradient echo or T2W images. If obtained, can also characterize on R2* (=1/T2*) maps.

Iron in mass, more than liver is present if **ALL** of the following are met:

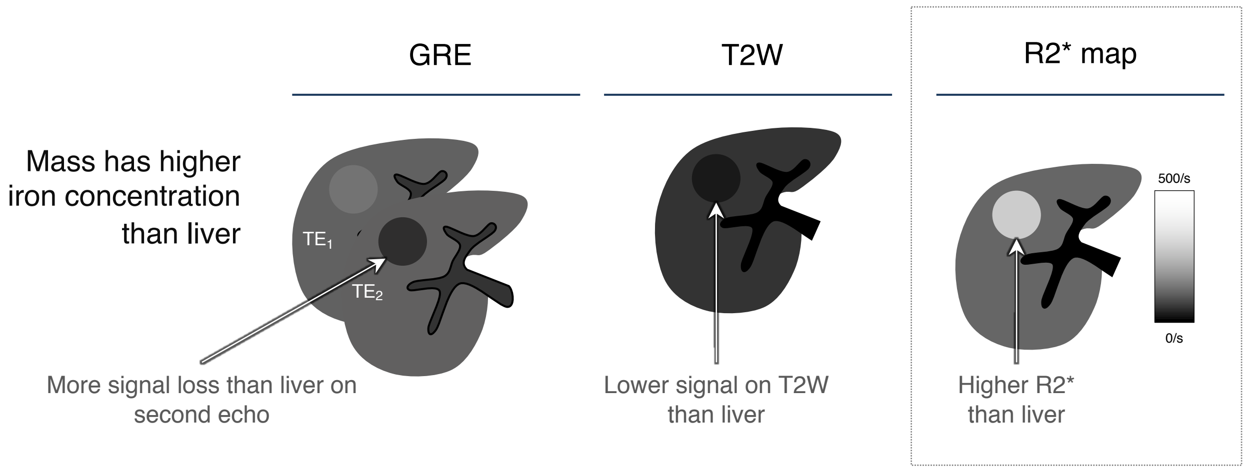
- The observation is a mass

  AND

- The observation is iron overloaded as evidenced by unequivocal signal loss on second echo compared to first echo **OR** markedly low signal on T2W images **OR** abnormally high R2* value on R2* maps

  AND

- The liver is less iron overloaded or non-iron overloaded (less or no signal loss on second echo, higher signal on T2W, lower or no R2* value elevation).



If obtained
(R2* maps are optional;
they are **not required** by LI-RADS)

Iron in Mass, More than Liver

RADLEX ID: N/A

Characterization (Cont'd)

On CT:

With caution, this feature sometimes can be characterized on CT.

Iron in mass, more than liver is present on CT if **ALL** of the following are met:

- The observation is a mass

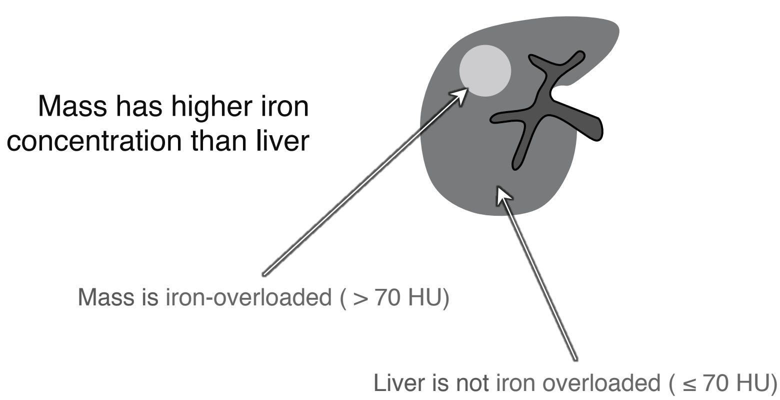
  AND

- The observation is unequivocally iron overloaded (attenuation > 70 HU)

  AND

- The liver is less iron-overloaded or non-iron-overloaded (attenuation ≤ 70 HU).

Unenhanced CT

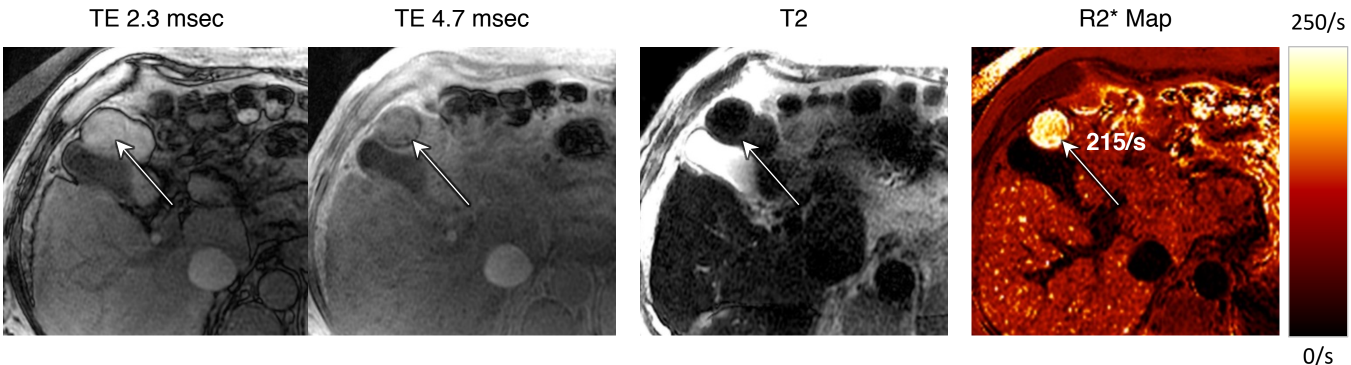


Iron in Mass, More than Liver

RADLEX ID: N/A

Characterization (Cont'd)

Example



Unequivocal signal loss on second echo compared to first echo images, greater than background

Markedly low signal

High R2* value indicating high iron content

If unsure

If unsure about iron in mass, do not characterize as iron in mass**.**

Pitfalls & practical considerations

T2* shortening from blood products may be mistaken for iron accumulation on T2*W sequences or on R2* (=1/T2*) maps

On older MR scanners that utilize IP-then-OP dual-echo design, fat in mass and iron in mass both manifest signal loss on the second echo, fat due to chemical shift of the second kind, iron due to T2* shortening. In such situations, scrutinize non-fat-suppressed T2W images: iron-overloaded mass will be hypointense, fatty mass will be iso or mildly hypointense.

Iron in mass may result in low signal in the TP and HBP, even in observations with preserved OATP expression, potentially causing mischaracterization as TP or HBP hypointensity (ancillary features favoring malignancy).

Mild T2 hypointensity may be seen in HCC and should not be confused with the marked T2 hypointensity of iron in mass. Mild T2 hypointensity in HCC has been attributed to copper accumulation, fibrinogen deposition, or fibrosis, but the mechanism is not well understood.

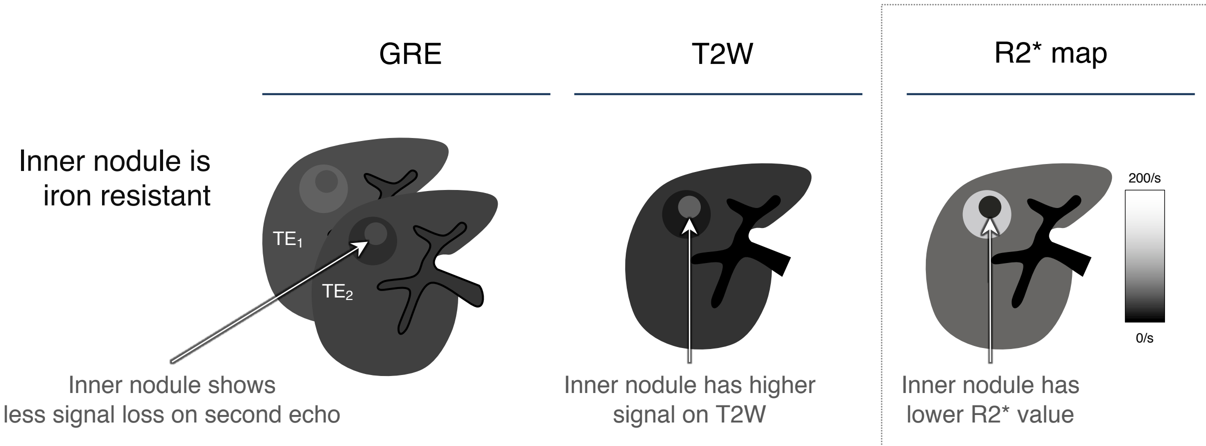
While hemorrhagic HCCs may contain blood products with short T2* components, the presence of iron is distinctly uncommon in non-hemorrhagic HCC.

Iron in Mass, More than Liver

RADLEX ID: N/A

Pitfalls & practical considerations (Cont'd)

Development of an iron-poor inner nodule within a siderotic outer nodule suggests incident high-grade dysplastic nodule or HCC. The inner nodule is thought to represent clonal expansion of premalignant or malignant cells with "iron resistance".



If obtained
(R2* maps are optional;
they are **not required** by LI-RADS)

Iron-poor (-resistant) inner nodule within a siderotic outer nodule is a type of nodule-in-nodule architecture. The inner nodule is probably a high-grade dysplastic nodule or HCC.

Iron in Mass, More than Liver

RADLEX ID: N/A

References

Krinsky GA, Lee VS, Nguyen MT, Rofsky NM, Theise ND, Morgan GR, et al. Siderotic nodules at MR imaging: regenerative or dysplastic? Journal of computer assisted tomography. 2000;24(5):773-6.

Krinsky GA, Lee VS, Nguyen MT, Rofsky NM, Theise ND, Morgan GR, et al. Siderotic nodules in the cirrhotic liver at MR imaging with explant correlation: no increased frequency of dysplastic nodules and hepatocellular carcinoma. Radiology. 2001;218(1):47-53.

Krinsky GA, Zivin SB, Thorner KM, Lee VS, Theise ND, Weinreb JC. Low-grade siderotic dysplastic nodules: determination of premalignant lesions on the basis of vasculature phenotype. Academic radiology. 2002;9(3):336-41.

Zhang J, Krinsky GA. Iron-containing nodules of cirrhosis. NMR Biomed. 2004;17(7):459-64.

Marked T2 Hyperintensity

RADLEX ID: RID39458

Definition

Intensity on T2WI markedly higher than liver and similar to bile ducts and other fluid-filled structures.

Synonyms

T2 bright, high T2 signal intensity, fluid signal

Terminology

Not applicable

Applicable modalities

MRI (all contrast agents)

Type of feature

Ancillary feature that favors benignity

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring malignancy, then marked T2 hyperintensity causes LR-2, LR-3, LR-4 or LR-5 observations to be downgraded by *one* category to LR-1, LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring benignity, marked T2 hyperintensity cannot be used to downgrade by two or more categories and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: marked T2 hyperintensity may cause the radiologist to question a prior LR-M or LR-TIV category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Biological basis

Homogeneous marked T2 hyperintensity is a feature of benign fluid-containing lesions (e.g. cysts and abscesses) and of lesions composed of vascular spaces filled with blood (e.g. hemangiomas). The presence of fluid or blood-filled vascular spaces prolongs T2 relaxation time which results in markedly high signal on T2W images.

Marked T2 Hyperintensity

RADLEX ID: RID39458

Summary of evidence

In studies in patients without and with underlying liver disease, high signal on heavily T2-weighted images has area under the curve of 0.97-0.98 for distinguishing hemangiomas from malignant solid lesions in the liver. Sensitivity and specificity ranges are 77-99% and 71-99%, respectively.

The incremental impact on diagnostic performance of marked T2 hyperintensity in combination with major features is not known.

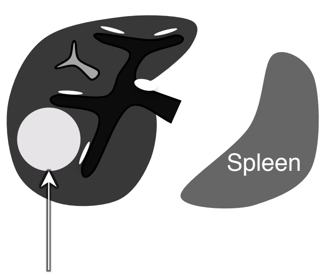
Characterization

Characterize on T2W images. If obtained, characterize on heavily T2W images.

Marked T2 hyperintensity is present if

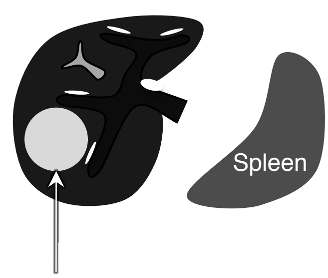
- Observation is homogeneous and markedly higher in signal than liver and than spleen, with intensity similar to simple fluid (e.g. bile ducts) on T2W images or, if obtained, heavily T2W images.

Marked T2 hyperintensity,
Standard T2W
TE ~100 ms



Observation is about as intense as bile ducts and much more intense than spleen.

Marked T2 hyperintensity,
Heavy T2W
TE ~200 ms



Marked hyperintensity may be more apparent on heavily T2W images

If obtained
(these types of images are optional;
they are **not required** by LI-RADS)

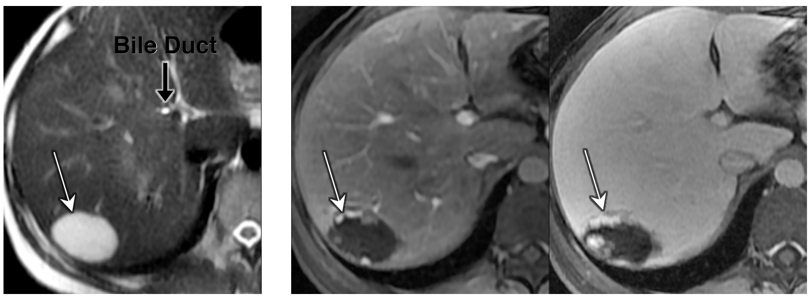
Marked T2 Hyperintensity

RADLEX ID: RID39458

Characterization (Cont'd)

Example: Benign hemangioma with marked T2 hyperintensity

T2 AP PVP



Marked homogeneous hyperintensity, similar to bile ducts

Early peripheral nodular discontinuous progressive enhancement, diagnostic of a hemangioma (*see* page 16-63).

If unsure

If unsure about marked T2 hyperintensity, do not characterize as marked T2 hyperintensity.

Pitfalls & practical considerations

Some primarily cystic neoplasms (e.g. biliary cystadenocarcinoma) and necrotic tumors may have T2 relaxation times comparable to benign cysts and manifest marked T2-hyperintensity. Thus, marked T2 hyperintensity favors benignity but by itself does not establish benignity with certainty.

Small hypervascular metastases may have very high signal on T2W sequences and homogeneous enhancement on arterial phase, potentially mimicking small hemangiomas. Inspection of multiphase and, if obtained, diffusion weighted and heavily T2W images can help in the differentiation:

- Unlike hemangiomas, most metastases do not parallel blood enhancement.
- Small hypervascular metastases tend to have greater diffusion restriction than hemangiomas.
- Hemangiomas remain markedly hyperintense relative to liver on heavily T2W images with very long TEs, whereas metastases usually do not.

Areas of necrosis in HCCs and other malignant neoplasms may have marked T2 hyperintensity, but these usually comprise only small parts of the observation. Apply marked T2 hyperintensity as an ancillary feature favoring benignity only if the observation is homogenously hyperintense.

Marked T2 Hyperintensity

RADLEX ID: RID39458

Pitfalls & practical considerations (Cont'd)

Although hemangiomas in the non-cirrhotic liver tend to be markedly T2 hyperintense, hemangiomas in the cirrhotic liver may become fibrotic (fibrosing or sclerosing hemangiomas) and can appear mildly-moderately T2 hyperintense. See *page 16-49* and *Chapter 15, page 6*.

Cysts and hemangiomas may appear more hyperintense on heavily T2W images with very long TEs compared to moderately T2W images with moderately long TEs. This is an optical illusion. The absolute signal intensity is lower on longer TE sequences. The signal may appear higher because the surrounding liver has lost more signal.

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Hepatobiliary Phase Isointensity

RADLEX ID: RID49814

Definition

Intensity in hepatobiliary phase (HBP) nearly identical to liver.

Synonyms

HBP isoenhancement, occult in HBP

Terminology

Not applicable

Applicable modalities

MRI with gadoxetate

Type of feature

Ancillary feature that favors benignity

Effect on categorization

If the radiologist elects to apply ancillary features and if there are no ancillary features favoring malignancy, then hepatobiliary isointensity causes LR-2, LR-3, LR-4 or LR-5 observations to be downgraded by *one* category to LR-1, LR-2, LR-3 or LR-4, respectively.

Like any other ancillary feature favoring benignity, HBP isointensity cannot be used to downgrade by two or more categories and should not be used to change LR-M or LR-TIV to a different category.

There is one **exception**: hepatobiliary isointensity may cause the radiologist to question a prior LR-M or LR-TIV category assignment, repeat the diagnostic algorithmic process, and consider assigning a new category.

Hepatobiliary Phase Isointensity

RADLEX ID: RID49814

Biological basis

Enhancement of the parenchyma on HBP reflects the balance between intracellular uptake and biliary excretion of the hepatobiliary agent by hepatocytes. Uptake by hepatocytes is mediated via membrane transporters known as organic anion transporting polypeptides (OATP). Biliary excretion by hepatocytes is mediated by canalicular transporters known as multidrug resistant proteins.

In general, benign hepatocytes have relatively high expression of organic anion transporting polypeptides, and the liver parenchyma tends to enhance fairly uniformly. By comparison, neoplastic hepatocytes (high-grade dysplastic nodules, HCCs) tend to under express or even lack organic anion transporting polypeptides and so appear as hypointense lesions relative to liver. Similarly, since organic anion transporting polypeptides are found only in hepatocytes, non-HCC malignancies lack the transporters entirely and also appear hypointense relative to liver.

Therefore, if an observation enhances uniformly and similarly to the adjacent parenchyma in the HBP, it suggests the observation is composed of benign hepatocytes with normal hepatocellular uptake and biliary excretion.

Summary of evidence

85-94% of nodular vascular pseudolesions demonstrate HBP isointensity. Conversely, 76% of early HCCs and 86% of well- or moderately differentiated HCCs demonstrate HBP hypointensity.

Hepatobiliary phase isointensity in combination with major features has a sensitivity of 91%–94% and a specificity of 93% to differentiate arterioportal shunt from HCC.

Hepatobiliary Phase Isointensity

RADLEX ID: RID49814

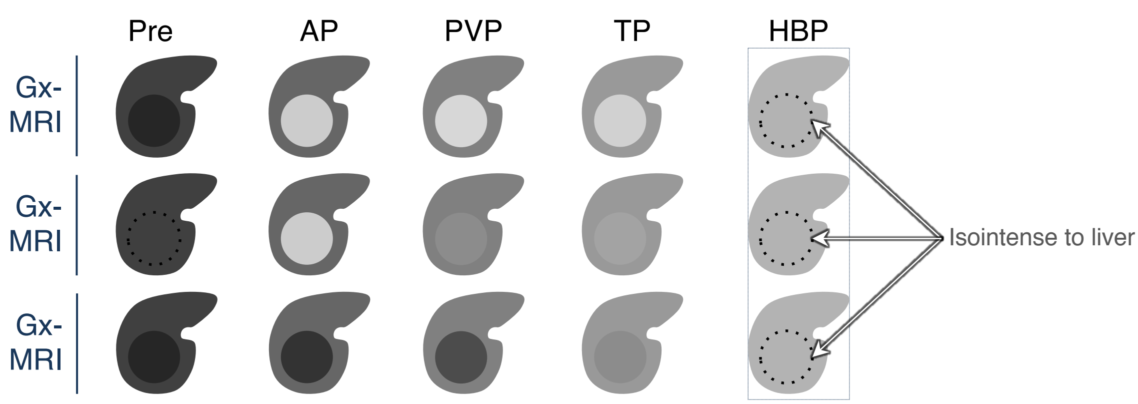
Characterization

Characterize on HBP images. If the observation is not visible in the HBP, then determine the location of the observation by co-localizing to the images in which it is visible.

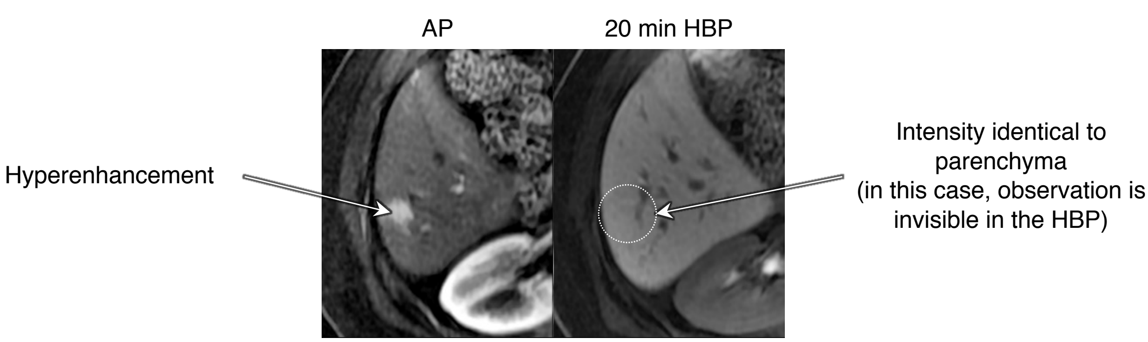
HBP isointensity is present if **BOTH** of the following are met:

- On HBP, the observation is identical or nearly identical to liver in intensity (it may even be invisible) **AND**
- HBP phase must be adequate (i.e. parenchyma enhances greater than intrahepatic vessels).

If the HBP is suboptimal, do not apply this feature. See *Chapter 13* for assessing HBP adequacy.



Example



If unsure

If unsure about HBP isointensity, do not characterize as HBP isointensity.

Hepatobiliary Phase Isointensity

RADLEX ID: RID49814

Pitfalls & practical considerations

If HBP phase is inadequate (e.g. the parenchyma does NOT have signal unequivocally higher than the signal of the vessels), this feature is not applicable. See *Chapter 13*.

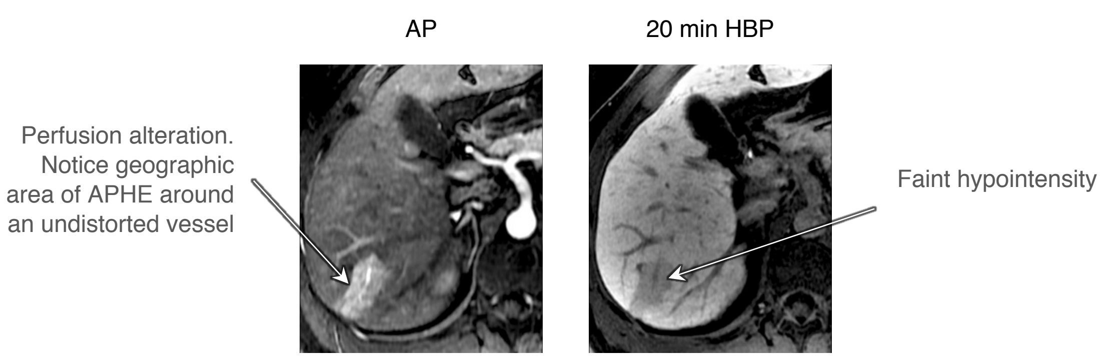
This feature is most useful for characterizing nodular arterial phase hyperenhancement (NAPH).

- A nodule-like area of hyperenhancement visible only in the AP is known as nodular arterial phase hyperenhancement (NAPH). NAPHs are thought to usually represent either perfusion alterations with a nodular configuration or small non-malignant hepatocellular nodules (e.g., hyperplastic nodule, dysplastic nodule), and rarely small HCC.
- HBP imaging can help differentiate between possibilities:
  - HBP isointensity favors perfusion alteration (arterioportal shunt) or a non-malignant hepatocellular nodule.
  - HBP hypointensity favors premalignant or malignant hepatocellular neoplasm or a nonhepatocellular lesion.

Although homogeneous HBP isointensity is a frequent feature of vascular shunts and favors benignity, it does not exclude a dysplastic nodule (up to 16% of high-grade dysplastic nodules are isointense in the HBP) or small HCC (up to 5% of HCCs are isointense in the HBP). Please see *Chapter 13* for more information about HBP intensity of dysplastic nodules and HCC.

⚠ Since some HCCs can demonstrate isointensity on the HBP, use caution in applying this feature to downgrade an LR-5 observation.

Some perfusion alterations may show faint hypointensity rather than isointensity in the HBP. This probably reflects slight loss of function of hepatocytes exposed to greater than normal arterial flow and lower than normal portal flow.



Hepatobiliary Phase Isointensity

RADLEX ID: RID49814

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