American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 1: **Indeterminate >1 cm lesion on initial imaging with ultrasound. Normal liver. (No suspicion or evidence of extrahepatic malignancy or underlying liver disease.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	MRI is the best test for characterizing liver lesions.	O
CT abdomen without and with IV contrast	7	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢☢
CT abdomen with IV contrast	7	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢
MRI abdomen without IV contrast	6	Consider this procedure if MRI with gadolinium is contraindicated.	O
Percutaneous image-guided biopsy liver	5	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after doing contrast-enhanced CT or MRI.	Varies
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to MRI and CT contrast agents.	☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI contrast agents.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI contrast agents.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 2: **Indeterminate >1 cm lesion on initial imaging with CT (without or with contrast). Normal liver. (No suspicion or evidence of extrahepatic malignancy or underlying liver disease.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure if CT characterization is incomplete.	O
MRI abdomen without IV contrast	7	Consider this procedure if MRI with gadolinium is contraindicated. A noncontrast-enhanced MRI is superior to a noncontrast-enhanced CT.	O
US abdomen	5	Consider this procedure to diagnose a cyst versus solid lesion and to guide a percutaneous biopsy.	O
Percutaneous image-guided biopsy liver	5	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after doing contrast-enhanced CT or MRI.	Varies
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI contrast agents.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI contrast agents.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 3: **Indeterminate >1 cm lesion on initial imaging with noncontrast-enhanced MRI. Normal liver. (No suspicion or evidence of extrahepatic malignancy or underlying liver disease.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure to differentiate between benign and malignant lesion.	O
CT abdomen without and with IV contrast	7	Consider this procedure if MRI with gadolinium is contraindicated.	☢☢☢☢
CT abdomen with IV contrast	6	Consider this procedure if there is a contraindication to MRI contrast agents.	☢☢☢
US abdomen	5	This procedure is usually not indicated after MRI.	O
Percutaneous image-guided biopsy liver	5	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after doing contrast-enhanced CT or MRI.	Varies
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to CT and MRI contrast agents.	☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI contrast agents.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI contrast agents.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 4: **Indeterminate >1 cm lesion on initial imaging with ultrasound. Known history of an extrahepatic malignancy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure if the lesion is not cystic on US.	O
MRI abdomen without IV contrast	7	Consider this procedure if there is a contraindication to CT and MRI contrast agents.	O
CT abdomen without and with IV contrast	7	Consider this procedure if the lesion is not cystic on US.	☢☢☢☢
CT abdomen with IV contrast	7	Consider this procedure if there is a contraindication to MRI.	☢☢☢
Percutaneous image-guided biopsy liver	7	Consider this procedure for obtaining a tissue diagnosis and when imaging is not conclusive.	Varies
FDG-PET/CT whole body	6	This procedure may be appropriate for complete staging based on size and avidity of the primary extrahepatic malignancy.	☢☢☢☢
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to MRI and CT contrast agents. A noncontrast-enhanced MRI is superior to a noncontrast-enhanced CT.	☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI contrast agents.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI contrast agents.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	Consider this procedure if the primary lesion is a neuroendocrine tumor and/or when symptoms or laboratory values indicate a neuroendocrine malignancy.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 5: **Indeterminate >1 cm lesion on initial imaging with CT (without or with contrast). Known history of an extrahepatic malignancy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure if CT characterization is incomplete.	O
Percutaneous image-guided biopsy liver	7	Consider this procedure for obtaining a tissue diagnosis and when imaging is not conclusive.	Varies
MRI abdomen without IV contrast	6	A noncontrast-enhanced MRI is superior to a noncontrast-enhanced CT.	O
FDG-PET/CT whole body	6	This procedure may be appropriate for complete staging based on size and avidity of the primary extrahepatic malignancy.	☢☢☢☢
US abdomen	5	Consider this procedure if CT was performed without contrast and MRI is contraindicated.	O
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI contrast agents.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI contrast agents.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	Consider this procedure if the primary lesion is a neuroendocrine tumor and/or when symptoms or laboratory values indicate a neuroendocrine malignancy.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 6: **Indeterminate >1 cm lesion on initial imaging with noncontrast-enhanced MRI. Known history of an extrahepatic malignancy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure to differentiate between benign and malignant lesion.	O
CT abdomen without and with IV contrast	7	Consider this procedure if MRI with gadolinium is contraindicated.	☢☢☢☢
CT abdomen with IV contrast	7	Consider this procedure if there is a contraindication to MRI contrast agents.	☢☢☢
Percutaneous image-guided biopsy liver	7	Consider this procedure for obtaining a tissue diagnosis and when imaging is not conclusive.	Varies
FDG-PET/CT whole body	6	This procedure may be appropriate for complete staging based on size and avidity of the primary extrahepatic malignancy.	☢☢☢☢
US abdomen	5	Consider this procedure to differentiate between a cystic versus solid lesion or to guide a biopsy/intervention.	O
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to MRI and CT contrast agents. A noncontrast-enhanced MRI is superior to a noncontrast-enhanced CT.	☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI contrast agents.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI contrast agents.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	Consider this procedure if the primary lesion is a neuroendocrine tumor and/or when symptoms or laboratory values indicate a neuroendocrine malignancy.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 7: **Indeterminate >1 cm lesion on initial imaging with ultrasound. Known or suspected liver disease associated with a high risk of hepatocellular carcinoma (chronic hepatitis, cirrhosis, hemochromatosis, etc.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	9	This is the best test for surveillance of hepatitis B or C.	O
CT abdomen without and with IV contrast	7	This procedure is an alternative to MRI when GFR precludes gadolinium.	☢☢☢☢
MRI abdomen without IV contrast	6	Consider this procedure if there is a contraindication to CT and MRI contrast agents.	O
CT abdomen with IV contrast	6	Consider this procedure if there is a contraindication to MRI or MRI contrast agents.	☢☢☢
Percutaneous image-guided biopsy liver	6	This procedure is useful if alpha-fetoprotein is low or features are not typical.	Varies
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to MRI and CT contrast agents. A noncontrast-enhanced MRI is superior to a noncontrast-enhanced CT.	☢☢☢
Tc-99m sulfur colloid scan liver	3	FNH is not common in patients with cirrhosis.	☢☢☢
Tc-99m RBC scan liver	3	A hemangioma is not common in patients with cirrhosis.	☢☢☢
In-111 somatostatin receptor scintigraphy	2	This procedure is not relevant to the detection or characterization of HCC.	☢☢☢☢
FDG-PET/CT whole body	2	This procedure is not useful for HCC staging.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 8: **Indeterminate >1 cm lesion on initial imaging with CT (without or with contrast). Known or suspected liver disease associated with a high risk of hepatocellular carcinoma (chronic hepatitis, cirrhosis, hemochromatosis, etc.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	9	Consider this procedure if CT is not conclusive and in scenarios where there has been prior intervention (ie, radiofrequency/ablation, chemoembolization).	O
MRI abdomen without IV contrast	6	Consider this procedure if CT is not conclusive and there is a contraindication to gadolinium.	O
Percutaneous image-guided biopsy liver	6	This procedure is useful if alpha-fetoprotein is low or features are not typical.	Varies
US abdomen	5	Consider this procedure to differentiate between a cystic versus solid lesion or to guide a biopsy/intervention.	O
Tc-99m sulfur colloid scan liver	3	FNH is not common in patients with cirrhosis.	☢☢☢
Tc-99m RBC scan liver	3	A hemangioma is not common in patients with cirrhosis.	☢☢☢
In-111 somatostatin receptor scintigraphy	2	This procedure is not relevant to the detection or characterization of HCC.	☢☢☢☢
FDG-PET/CT whole body	2	This procedure is not useful for HCC staging.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 9: **Indeterminate >1 cm lesion on initial imaging with noncontrast-enhanced MRI. Known or suspected liver disease associated with a high risk of hepatocellular carcinoma (chronic hepatitis, cirrhosis, hemochromatosis, etc.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	9		O
CT abdomen without and with IV contrast	7	Consider this procedure as an alternative to MRI when GFR precludes use of gadolinium.	☢☢☢☢
CT abdomen with IV contrast	6	Consider this procedure as an alternative to MRI when GFR precludes use of gadolinium.	☢☢☢
Percutaneous image-guided biopsy liver	6	This procedure is useful if alpha-fetoprotein is low or features are not typical.	Varies
US abdomen	5	Consider this procedure to confirm a cystic lesion.	O
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to MRI and CT contrast agents. A noncontrast-enhanced MRI is superior to a noncontrast-enhanced CT.	☢☢☢
Tc-99m sulfur colloid scan liver	3	FNH is not common in patients with cirrhosis.	☢☢☢
Tc-99m RBC scan liver	3	A hemangioma is not common in patients with cirrhosis.	☢☢☢
In-111 somatostatin receptor scintigraphy	2	This procedure is not relevant to the detection or characterization of HCC.	☢☢☢☢
FDG-PET/CT whole body	2	This procedure is not useful for HCC staging.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 10: **Indeterminate <1 cm lesion on initial imaging with ultrasound. Normal liver. (No suspicion or evidence of extrahepatic malignancy or underlying liver disease.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8		O
CT abdomen without and with IV contrast	7	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢☢
MRI abdomen without IV contrast	6	Consider this procedure if MRI with gadolinium is contraindicated.	O
CT abdomen with IV contrast	6	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to MRI and CT contrast agents.	☢☢☢
Percutaneous image-guided biopsy liver	3	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
In-111 somatostatin receptor scintigraphy	2	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 11: **Indeterminate <1 cm lesion on initial imaging with CT (without or with contrast). Normal liver. (No suspicion or evidence of extrahepatic malignancy or underlying liver disease.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure if characterization by CT is incomplete.	O
MRI abdomen without IV contrast	6	Consider this procedure if MRI with gadolinium is contraindicated. A noncontrast-enhanced MRI is superior to a noncontrast-enhanced CT. However, this may not be the case for small lesions.	O
US abdomen	5	Consider this procedure to differentiate between a cystic versus solid lesion or to guide a biopsy/intervention.	O
Percutaneous image-guided biopsy liver	3	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
In-111 somatostatin receptor scintigraphy	2	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 12: **Indeterminate <1 cm lesion on initial imaging with noncontrast-enhanced MRI. Normal liver. (No suspicion or evidence of extrahepatic malignancy or underlying liver disease.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure to differentiate between benign and malignant lesion. However, there may be challenges when attempting to characterize small lesions.	O
CT abdomen without and with IV contrast	7	Consider this procedure if MRI with gadolinium is contraindicated.	☢☢☢☢
CT abdomen with IV contrast	6	Consider this procedure if there is a contraindication to MRI contrast agents.	☢☢☢
US abdomen	5	This procedure is usually not indicated after MRI.	O
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to CT and MRI contrast agents.	☢☢☢
Percutaneous image-guided biopsy liver	3	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
In-111 somatostatin receptor scintigraphy	2	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 13: **Indeterminate <1 cm lesion on initial imaging with ultrasound. Known history of an extrahepatic malignancy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Although MRI is the best test for characterizing liver lesions, it may have limitations for characterizing small lesions.	O
CT abdomen without and with IV contrast	7	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢☢
CT abdomen with IV contrast	7	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢
MRI abdomen without IV contrast	6	Consider this procedure if MRI with gadolinium is contraindicated.	O
Percutaneous image-guided biopsy liver	6	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing a CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
FDG-PET/CT whole body	4	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to MRI and CT contrast agents.	☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 14: **Indeterminate <1 cm lesion on initial imaging with CT (without or with contrast). Known history of an extrahepatic malignancy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure if characterization by CT is incomplete, recognizing the limitations of MRI for characterizing small lesions.	O
MRI abdomen without IV contrast	6	Consider this procedure if MRI with gadolinium is contraindicated.	O
Percutaneous image-guided biopsy liver	6	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing a CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
US abdomen	5	Consider this procedure to differentiate between a cystic versus solid lesion or to guide a biopsy/intervention.	O
FDG-PET/CT whole body	4	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 15: **Indeterminate <1 cm lesion on initial imaging with noncontrast-enhanced MRI. Known history of an extrahepatic malignancy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	8	Consider this procedure to differentiate between benign and malignant lesion. However, there may be challenges when attempting to characterize small lesions.	O
CT abdomen without and with IV contrast	7	Consider this procedure if MRI with gadolinium is contraindicated.	☢☢☢☢
CT abdomen with IV contrast	7	Consider this procedure if there is a contraindication to MRI contrast material.	☢☢☢
Percutaneous image-guided biopsy liver	6	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing a CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
US abdomen	4	This procedure is usually not indicated after MRI.	O
FDG-PET/CT whole body	4	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to CT and MRI contrast agents.	☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 16: **Indeterminate <1 cm lesion on initial imaging with ultrasound. Known or suspected liver disease associated with a high risk of hepatocellular carcinoma (chronic hepatitis, cirrhosis, hemochromatosis, etc.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	9	Although MRI is the best test for characterizing liver lesions, it may have limitations for characterizing small lesions.	O
CT abdomen without and with IV contrast	7	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢☢
MRI abdomen without IV contrast	6	Consider this procedure if MRI with gadolinium is contraindicated. However, this may not be the case for small lesions.	O
CT abdomen with IV contrast	6	Consider this procedure if the lesion is not cystic on US and MRI is not available or contraindicated.	☢☢☢
Percutaneous image-guided biopsy liver	6	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
CT abdomen without IV contrast	2	Consider this procedure if there is a contraindication to MRI and CT contrast agents.	☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 17: **Indeterminate <1 cm lesion on initial imaging with CT (without or with contrast). Known or suspected liver disease associated with a high risk of hepatocellular carcinoma (chronic hepatitis, cirrhosis, hemochromatosis, etc.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	9	Consider this procedure if characterization by CT is incomplete, recognizing the limitations of MRI for characterizing small lesions.	O
MRI abdomen without IV contrast	6	Consider this procedure if MRI with gadolinium is contraindicated.	O
Percutaneous image-guided biopsy liver	6	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
US abdomen	5	Consider this procedure to differentiate between a cystic versus solid lesion or to guide a biopsy/intervention.	O
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Liver Lesion—Initial Characterization**

Variant 18: **Indeterminate <1 cm lesion on initial imaging with noncontrast-enhanced MRI. Known or suspected liver disease associated with a high risk of hepatocellular carcinoma (chronic hepatitis, cirrhosis, hemochromatosis, etc.)**

Radiologic Procedure	Rating	Comments	RRL*
MRI abdomen without and with IV contrast	9	Consider this procedure to differentiate between benign and malignant lesion. However, there may be challenges when attempting to characterize small lesions.	O
CT abdomen without and with IV contrast	7	Consider this procedure if MRI with gadolinium is contraindicated and knowledge of the enhancement pattern will help with the differential diagnosis.	☢☢☢☢
CT abdomen with IV contrast	6	Consider this procedure if there is a contraindication to MRI contrast agents.	☢☢☢
Percutaneous image-guided biopsy liver	6	Consider this procedure if imaging findings are atypical, inconclusive, or suspicious for malignancy after performing CT or MRI with contrast. However, there may be challenges when attempting to biopsy small lesions.	Varies
US abdomen	5	This procedure is usually not indicated after MRI.	O
CT abdomen without IV contrast	3	Consider this procedure if there is a contraindication to CT and MRI contrast agents.	☢☢☢
Tc-99m sulfur colloid scan liver	3	Consider this procedure to evaluate for FNH if GFR precludes CT or MRI with contrast.	☢☢☢
Tc-99m RBC scan liver	3	Consider this procedure if a hemangioma is suspected and if GFR precludes CT or MRI with contrast.	☢☢☢
In-111 somatostatin receptor scintigraphy	3	This procedure is not appropriate unless there is a known or suspected neuroendocrine tumor.	☢☢☢☢
FDG-PET/CT whole body	3	This procedure is not appropriate unless there is a known malignancy.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Expert Panel on Gastrointestinal Imaging: Rendon C. Nelson, MD[1]; Ihab R. Kamel, MD, PhD[2]; Mark E. Baker, MD[3]; Waddah B. Al-Refaie, MD[4]; Brooks D. Cash, MD[5]; Stephen A. Harrison, MD[6]; Nicole M. Hindman, MD[7]; Harmeet Kaur, MD[8]; Michelle M. McNamara, MD[9]; Aliya Qayyum, MD[10]; Mark Tulchinsky, MD[11]; Gail M. Yarmish, MD[12]; Max P. Rosen, MD, MPH.[13]

Summary of Literature Review

Introduction/Background

Due to the high prevalence of benign focal hepatic lesions in adults, liver lesion characterization is an important objective of diagnostic imaging. Incidental liver masses are often discovered in healthy adults during routine imaging procedures as well as during staging of a known malignancy, and they need to be characterized.

Common benign liver masses include cysts, biliary hamartomas, and hemangiomas; common malignant tumors include metastases and hepatocellular carcinomas (HCCs). Less common liver tumors include focal nodular hyperplasia (FNH), hepatocellular adenoma, fibrolamellar HCC, intrahepatic cholangiocarcinoma, biliary cystadenoma and cystadenocarcinoma, lymphoma, stromal tumors, a variety of sarcomas, hemangioendothelioma, and hepatoblastoma, the latter occurring in children. On occasion, nontumorous masses may mimic liver tumors. These mimics include focal fat deposition or sparing, abscess, hematoma, vascular shunts such as the ones to treat portal venous-hepatic venous malformations, peliosis hepatis and transient hepatic attenuation differences on computed tomography (CT), or transient hepatic intensity differences on magnetic resonance imaging (MRI). Patients with cirrhosis are a special group in whom certain benign (regenerating nodules), premalignant (dysplastic nodules), malignant (HCC), and nontumorous (confluent hepatic fibrosis) masses are more prevalent.

For each of the variants in this document, it is assumed that some prior imaging study has been performed that has identified a lesion that may or may not be characterized by the initial imaging evaluation or it is assumed that the initial technique was suboptimal from a technical standpoint. Prior imaging studies may include ultrasonography (US) with color-flow evaluation, noncontrast and/or contrast-enhanced multidetector helical CT, or noncontrast and/or contrast-enhanced MRI.

This topic has been addressed somewhat differently in the White Paper of the ACR Incidental Findings Committee [1]. That document attempted to address what to do with an incidental liver lesion detected on CT only. Masses were divided into 3 size categories (<0.5 cm, 0.5 cm–1.5 cm, and >1.5 cm) and then stratified based on size, risk factors, and/or CT imaging characteristics into benign or suspicious. This ACR Appropriateness Criteria® (AC) document addresses if and how to characterize a hepatic mass detected with any modality.

For purposes of increased clarity, in this AC, we combined the low-risk and average-risk individuals into one category using the definitions as stated in the white paper (any age with no known malignancies, hepatic dysfunction, hepatic cancer risk factors, or symptoms attributable to the liver). The definition of a high-risk individual in this AC differs from the white paper in that we separate those individuals with pre-existing liver disease (cirrhosis, hepatitis, chronic active hepatitis, sclerosing cholangitis, primary biliary cirrhosis, hemochromatosis, hemosiderosis, and hepatic dysfunction) from those with a known primary malignancy. Lastly, we use a size cutoff ≤1 cm as there are no data to support a different approach for patients with lesions <5 mm and 5–10 mm. In this revision, we added 3 more clinical variants for indeterminate masses <1 cm in size: <1 cm lesion, low-risk, and average-risk individual; <1 cm, high-risk individual, suspected metastatic disease, known extrahepatic malignancy (EHM); <1 cm, high-risk individual with underlying liver disease.

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Variant Development

"Liver lesion characterization" is undertaken for hepatic masses seen by US, CT, or MRI. For the variant analysis, one can consider the following combination of lesion characteristics and clinical risk factors:

I. Lesion characteristics (size and appearance)

- *Larger than 1 cm*
  - *Typical benign:* Liver lesion with a US, CT, or MRI imaging appearance that is diagnostic or highly suggestive of a benign mass (cyst, hemangioma, focal fat, or FNH). This may occur in a patient with or without a known history of malignancy.
  - *Typical malignant*: Liver lesion with a US, CT, or MRI imaging appearance that is highly suggestive of a malignant mass (HCC, cholangiocarcinoma, or metastases) in a patient who may or may not have a known malignancy.
  - *Indeterminate (variants 1–9):* Liver lesion with a US, CT, or MRI imaging appearance that is indeterminate. This may occur in a patient with a background of normal liver, chronic liver disease, or known extrahepatic primary malignancy.
- *Smaller than 1 cm indeterminate:* Liver lesion <1 cm with a US, CT, or MRI appearance that is indeterminate, regardless of clinical history.

II. Clinical risk factors

- History of EHM.
- Underlying history of liver disease (eg, cirrhosis, hepatitis B or C, primary sclerosing cholangitis, steatohepatitis).

Diagnostic Tests

To characterize a liver lesion discovered by US, CT, or MRI, the following diagnostic studies may be considered:

- Dynamic contrast-enhanced CT (multidetector helical).
- MRI (including contrast enhancement with gadolinium chelates).
- Sonography: Routine grayscale and Doppler US.
- CT/positron emission tomography (PET) with fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG).
- Nuclear scintigraphy (Tc-99m sulfur colloid or Tc-99m red blood cell (RBC), octreoscan).
- Percutaneous image-guided biopsy.

When considering possible studies for liver lesion characterization, it is assumed that a logical sequence will be followed. For example, if MRI and biopsy are considered appropriate tests, it is assumed that the biopsy will be done if the MRI is nondiagnostic. In this case, both studies should be considered to be "indicated."

Special Considerations

- *Lesions previously characterized as benign:* For a lesion previously characterized as benign, follow-up imaging is not usually indicated unless the patient has new symptoms or there is a change in the size, attenuation, signal intensity, or degree/pattern of enhancement of a benign lesion, which is a cause for concern [2,3].
- *Indeterminate lesions:* For indeterminate liver lesions >1 cm in all other categories described above, a biopsy should be considered when the findings from the additional imaging tests are inconclusive. Alternatively, in certain clinical situations, short-term imaging surveillance (3–4 months) can be useful to monitor lesion stability. Depending on the stability of the lesion or the underlying disease process, interval scans may be extended over longer periods (eg, 6–12 months) and repeated as necessary, especially in the setting of underlying liver disease.
- *Subcentimeter lesion:* These lesions are difficult to characterize, although MRI may be helpful [4-8]. In patients with extrahepatic primary malignancy, these small lesions are often evaluated with follow-up imaging since most are benign [1,5-11].

Contrast Agents

Ultrasound Contrast Agents

Research performed outside the United States on second-generation ultrasound (US) contrast agents has demonstrated high accuracy in characterizing liver lesions [12-30]. These agents consist of either stable perfluorocarbon nanoparticles or sulphur hexafluoride microbubbles; they are injected intravenously and insonated with low acoustic pressure. The nanoparticles emit a harmonic signal that can be detected with pulse inversion recovery to demonstrate the vascular architecture of a lesion, as well as the temporal course of enhancement, thereby allowing characterization of the lesion. These agents have not been approved for hepatic imaging in the United States.

MRI Contrast Agents

MRI contrast agents such as mangafodipir and ferumoxides may be of value for distinguishing between benign and malignant primary hepatocellular tumors and for detecting metastatic disease. However, experience with the use of these agents is mainly limited to phase III clinical trials, and they are not widely available for clinical use [31]. At this time, mangafodipir is not available for clinical use in the United States.

Gadobenate dimeglumine can be used to differentiate FNH from other lesions such as hepatocellular adenoma. Approximately 5% of this agent is metabolized by the liver, accumulating in the biliary ductule cells present in FNH and resulting in mild persistent enhancement on delayed imaging at 1–3 hours after contrast administration [31-34]. Newer liver-specific agents such as gadoxetic acid have approximately 50% hepatic uptake and metabolism, accumulating in healthy liver cells and resulting in persistent enhancement of the background liver and no enhancement of lesions that do not contain functioning hepatocytes. With this agent, there is mild to vivid enhancement of FNH on delayed imaging at 10–20 minutes after contrast administration. FNH is not known to occur in the cirrhotic liver. Therefore, delayed uptake in such cases should not favor a benign process since well-differentiated HCC may have functioning hepatocytes. These newer agents enable a delayed hepatobiliary phase in addition to hepatic arterial, portal venous, and equilibrium phase MR imaging for lesion detection and characterization [31-46].

Recommendations (Appendix 1 and Appendix 2)

- *Typical benign mass: no history of malignancy.* Liver masses with typical imaging features of simple cyst, hemangioma, hepatocellular adenoma, or FNH in patients who are not known to have or are not suspected of having a malignancy may be classified as benign [2,3,47-49]. Focal fat deposition or focal sparing in a liver with otherwise diffuse fat deposition can generally be diagnosed when typical features are seen on sonography, noncontrast CT, and, most reliably, MRI using chemical shift (in phase and out of phase) imaging [31,47]. These typical benign lesions do not require further follow-up if they have been characterized as a benign process [2,3,48,49].

- *Typical benign mass: known history of malignancy*. Liver masses with typical imaging features of simple cyst, hemangioma, or FNH in patients who are known to have a malignancy may be considered benign [2,3,27,47-49] and do not require follow-up. However, if there is any doubt that the mass is benign, tumor markers, short-interval follow-up imaging, or biopsy should be considered.

- *Typical malignant mass.* Lesions with typical imaging features of a malignant mass do not require additional imaging, but confirmation with serum tumor markers (eg, alpha fetoprotein in the case of HCC) or percutaneous image-guided biopsy may be appropriate [50,51]. In some cases, additional imaging such as nuclear scintigraphy (somatostatin receptor) or PET/CT can be performed to fully stage the extent of disease prior to an invasive biopsy [52-59], particularly if there is a history of primary EHM.

- *Indeterminate mass >1 cm: low-risk or average-risk individual (variants 1–3).* For indeterminate masses on a background of normal liver, additional imaging may be required for further characterization.

  If the initial indeterminate imaging test is US or CT, then MRI should be considered for liver lesion characterization [31,47,60-69]. MRI would be particularly preferred in pediatric and young adult patients due to its lack of ionizing radiation. Nuclear scintigraphy is an option in patients with suspected FNH (using technetium-labeled sulfur colloid). US can have a role in cases of T2 hyperintense lesions found on MRI as well as hypodense lesions found on CT to determine whether they are solid or cystic or to confirm a hemangioma.

- *Indeterminate mass >1 cm: high-risk individual, suspect metastatic disease, known EHM (variants 4–6)*. In these patients, interval follow-up imaging is usually not a practical option due to the need to initiate appropriate treatment. Dynamic contrast-enhanced, multiphase, multidetector CT, multiphase MRI (with a gadolinium-chelate) [55,70], or contrast-enhanced US (only available outside the United States) [12,13,15-23,25-30] may be used to characterize a lesion further and identify additional lesions in the setting of metastatic disease. Percutaneous image-guided liver biopsy should always be considered and will enable tissue diagnosis [51].

  If the underlying extrahepatic primary malignancy is FDG avid (eg, melanoma, colorectal cancer, esophageal cancer, breast cancer, sarcoma) and the diagnosis of liver metastasis will influence patient management [52-59], PET/CT imaging may be useful. Note, however, that metastases from mucin-producing colorectal carcinoma may not be FDG avid. Furthermore, HCC may not be FDG avid. Nuclear scintigraphy is also an option for further staging in patients with an underlying primary neuroendocrine malignancy (somatostatin receptor scintigraphy) [53].

- *Indeterminate mass >1 cm: high-risk individual with underlying liver disease (variants 7–9)*. Characterization of liver lesions in a cirrhotic liver may be performed with either multiphase MRI (with a gadolinium-chelate) or dynamic contrast-enhanced multiphase, multidetector CT [10,35-38,41,42,69,71-80]. Characterization is more definitive for lesions >2 cm in diameter [4,6]. MRI may be useful to characterize indeterminate masses identified on CT or US. If the mass remains indeterminate after MRI, then percutaneous image-guided biopsy may be needed to make a final diagnosis [50,51]. Percutaneous biopsy may not be indicated in patients who are liver transplant candidates due to the risk of needle-tract seeding. In such cases, short-term follow-up imaging in 3–6 months may be obtained. Digital subtraction angiography may also be obtained in these patients, and if a tumor stain is detected, chemoembolization is performed as a bridge to transplantation.

- *Subcentimeter lesion.* Subcentimeter lesions can be benign or malignant, although the majority are benign, even in a patient with a known EHM [6]. Benign lesions are usually a result of a hepatobiliary fibrocystic continuum such as biliary hamartomas, microhamartomas, and simple cysts. Small hepatic cysts can also be seen in patients who have experienced a prior insult such as a biopsy of or trauma to the liver. These subcentimeter lesions are often nonspecific on US and CT partly due to their small size and volume averaging [1]. MRI may help confirm their cystic nature and benignity, especially in a patient with underlying malignancy [6,7] or chronic liver disease [10]. When a subcentimeter lesion is poorly detected or indeterminate on MRI and there is either underlying liver disease or extrahepatic malignancy, where there is greater risk of a malignant lesion, initial short-term surveillance (3 months) can be useful to monitor lesion stability. Depending on the stability of the lesion or the underlying disease process, interval scans can be extended over longer periods of time, eg, 6 months to 1 year [6,7]. In the case of extrahepatic malignancy, contrast-enhanced CT is most efficacious for whole-body staging unless a low glomerular filtration rate (GFR) precludes an enhanced examination. For patients with underlying liver disease, MRI may be more helpful for further characterization, specifically in delineating regenerative, siderotic, or dysplastic nodules as well as HCC.

- Additional variants have been created to deal with small indeterminate lesions:

  - Indeterminate <1 cm mass in a low-risk or average-risk individual (variants 10–12): In almost all low-risk or average-risk individuals, an indeterminate <1 cm liver lesion is benign. If indeterminate on US or CT, MRI may characterize the lesion. However, unless there is patient anxiety, one could argue that no further characterization of these lesions is indicated. The best course may be to perform no further imaging. If patient anxiety is high, a follow-up in 3–4 months, preferably with MRI, may allay their fears.

  - Indeterminate <1 cm lesion in a high-risk individual, with suspect metastatic disease, known EHM (variants 13–15): If a <1 cm lesion is detected with US or CT and cannot be fully characterized, MR may characterize the lesion as a cyst, hemangioma, hamartoma, or focal fat. If MR does not characterize the lesion, short-term follow-up (3–6 months) is recommended.

  - Indeterminate <1 cm mass in a high-risk individual with underlying liver disease (variants 16–18): If an indeterminate <1 cm lesion is detected with US in a patient with underlying liver disease, the differential diagnosis includes hyperplastic nodule, dysplastic nodule, or small HCC. Even though most of these lesions cannot be further characterized, given their size it is reasonable to obtain a multiphasic, enhanced

CT or precontrast and postcontrast-enhanced MRI, with MRI preferred to CT. Likewise, if an indeterminate <1 cm lesion is detected on a multiphasic, enhanced CT it is not unreasonable to seek further characterization with precontrast and postcontrast-enhanced MRI in 3 months.

Summary

- MRI without and with contrast is the technique of choice for the characterization of indeterminate focal liver lesions. This includes lesions of all sizes, even those <1 cm. It also includes patients without or with either EHM or chronic liver disease. When either an MRI with contrast or a CT with contrast is contraindicated in patients with renal insufficiency, especially when the eGFR is <30 mL/min, an MRI without contrast is the technique of choice.
- CT with contrast is the technique of choice for the characterization of indeterminate focal liver lesions in patients who cannot undergo an MRI with contrast, including lesions of all sizes and in patients without or with an EHM or chronic liver disease. When a survey examination of the entire abdomen and pelvis or the chest, abdomen, and pelvis is needed for the evaluation of patients with an EHM, a CT with contrast is preferred to an MRI. For most indications, a CT with contrast is preferred to an MRI without contrast. A CT without contrast, however, has a very limited role in the characterization of indeterminate focal liver lesions.
- US has a limited role in the characterization of indeterminate focal liver lesions, although it can be useful for differentiating solid from cystic lesions. It is very useful for guiding the percutaneous biopsy of a focal liver lesion, assuming, of course, that the lesion is visible with US.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

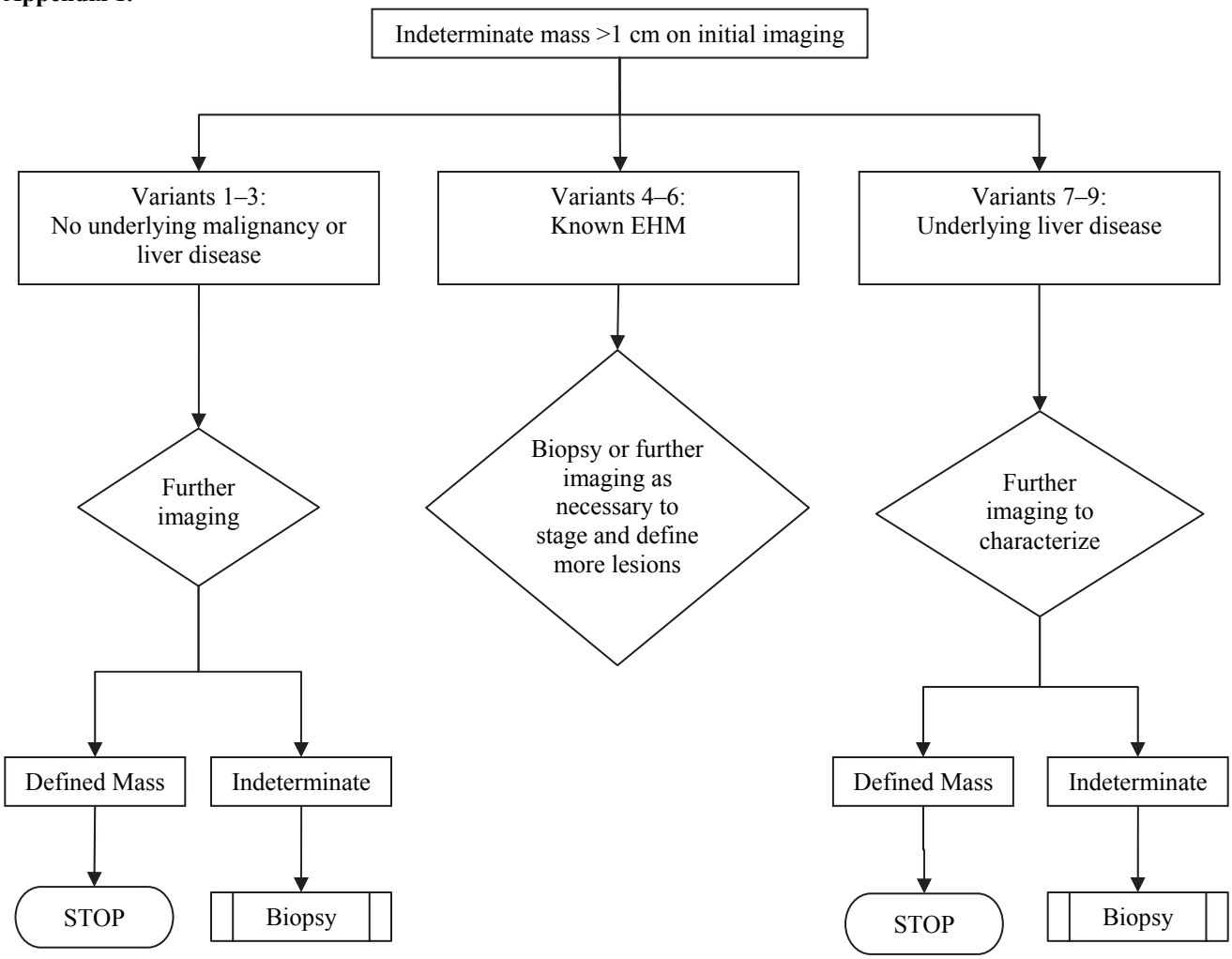
1. Berland LL, Silverman SG, Gore RM, et al. Managing incidental findings on abdominal CT: white paper of the ACR incidental findings committee. *J Am Coll Radiol.* 2010;7(10):754-773.
2. Leifer DM, Middleton WD, Teefey SA, Menias CO, Leahy JR. Follow-up of patients at low risk for hepatic malignancy with a characteristic hemangioma at US. *Radiology.* 2000;214(1):167-172.
3. Winterer JT, Kotter E, Ghanem N, Langer M. Detection and characterization of benign focal liver lesions with multislice CT. *Eur Radiol.* 2006;16(11):2427-2443.
4. Bolondi L, Gaiani S, Celli N, et al. Characterization of small nodules in cirrhosis by assessment of vascularity: the problem of hypovascular hepatocellular carcinoma. *Hepatology.* 2005;42(1):27-34.
5. Holalkere NS, Sahani DV, Blake MA, Halpern EF, Hahn PF, Mueller PR. Characterization of small liver lesions: Added role of MR after MDCT. *J Comput Assist Tomogr.* 2006;30(4):591-596.
6. Phongkitkarun S, Srianujata T, Jatchavala J. Supplement value of magnetic resonance imaging in small hepatic lesion (< or = 20 mm) detected on routine computed tomography. *J Med Assoc Thai.* 2009;92(5):677-686.
7. Schwartz LH, Gandras EJ, Colangelo SM, Ercolani MC, Panicek DM. Prevalence and importance of small hepatic lesions found at CT in patients with cancer. *Radiology.* 1999;210(1):71-74.
8. Holzapfel K, Bruegel M, Eiber M, et al. Characterization of small (</=10 mm) focal liver lesions: value of respiratory-triggered echo-planar diffusion-weighted MR imaging. *Eur J Radiol.* 2010;76(1):89-95.
9. Jang HJ, Kim TK, Wilson SR. Small nodules (1-2 cm) in liver cirrhosis: characterization with contrast-enhanced ultrasound. *Eur J Radiol.* 2009;72(3):418-424.
10. Khalili K, Kim TK, Jang HJ, Yazdi LK, Guindi M, Sherman M. Indeterminate 1-2-cm nodules found on hepatocellular carcinoma surveillance: biopsy for all, some, or none? *Hepatology.* 2011;54(6):2048-2054.
11. Laghi F, Catalano O, Maresca M, Sandomenico F, Siani A. Indeterminate, subcentimetric focal liver lesions in cancer patients: additional role of contrast-enhanced ultrasound. *Ultraschall Med.* 2010;31(3):283-288.
12. Jang HJ, Yu H, Kim TK. Contrast-enhanced ultrasound in the detection and characterization of liver tumors. *Cancer Imaging.* 2009;9:96-103.
13. Liu GJ, Wang W, Xie XY, et al. Real-time contrast-enhanced ultrasound imaging of focal liver lesions in fatty liver. *Clin Imaging.* 2010;34(3):211-221.
14. Martie A, Sporea I, Popescu A, et al. Contrast enhanced ultrasound for the characterization of hepatocellular carcinoma. *Med Ultrason.* 2011;13(2):108-113.
15. Moriyasu F, Itoh K. Efficacy of perflubutane microbubble-enhanced ultrasound in the characterization and detection of focal liver lesions: phase 3 multicenter clinical trial. *AJR Am J Roentgenol.* 2009;193(1):86-95.
16. Quaia E, Alaimo V, Baratella E, et al. Effect of observer experience in the differentiation between benign and malignant liver tumors after ultrasound contrast agent injection. *J Ultrasound Med.* 2010;29(1):25-36.
17. Sandulescu L, Saftoiu A, Dumitrescu D, Ciurea T. The role of real-time contrast-enhanced and real-time virtual sonography in the assessment of malignant liver lesions. *J Gastrointestin Liver Dis.* 2009;18(1):103-108.
18. Seitz K, Bernatik T, Strobel D, et al. Contrast-enhanced ultrasound (CEUS) for the characterization of focal liver lesions in clinical practice (DEGUM Multicenter Trial): CEUS vs. MRI--a prospective comparison in 269 patients. *Ultraschall Med.* 2010;31(5):492-499.
19. Seitz K, Strobel D, Bernatik T, et al. Contrast-Enhanced Ultrasound (CEUS) for the characterization of focal liver lesions - prospective comparison in clinical practice: CEUS vs. CT (DEGUM multicenter trial). Parts of this manuscript were presented at the Ultrasound Dreilandertreffen 2008, Davos. *Ultraschall Med.* 2009;30(4):383-389.
20. Sirli R, Sporea I, Popescu A, et al. Contrast enhanced ultrasound for the diagnosis of liver hemangiomas in clinical practice. *Med Ultrason.* 2011;13(2):95-101.
21. Sporea I, Badea R, Martie A, et al. Contrast enhanced ultrasound for the characterization of focal liver lesions. *Med Ultrason.* 2011;13(1):38-44.
22. Sporea I, Sirli R, Martie A, Popescu A, Danila M. How useful is contrast enhanced ultrasonography for the characterization of focal liver lesions? *J Gastrointestin Liver Dis.* 2010;19(4):393-398.
23. Wang WP, Wu Y, Luo Y, et al. Clinical value of contrast-enhanced ultrasonography in the characterization of focal liver lesions: a prospective multicenter trial. *Hepatobiliary Pancreat Dis Int.* 2009;8(4):370-376.

24. Xiao JD, Zhu WH, Shen SR. Evaluation of hepatocellular carcinoma using contrast-enhanced ultrasonography: correlation with microvessel morphology. *Hepatobiliary Pancreat Dis Int.* 2010;9(6):605-610.
25. Bartolotta TV, Midiri M, Quaia E, et al. Liver haemangiomas undetermined at grey-scale ultrasound: contrast-enhancement patterns with SonoVue and pulse-inversion US. *Eur Radiol.* 2005;15(4):685-693.
26. Celli N, Gaiani S, Piscaglia F, et al. Characterization of liver lesions by real-time contrast-enhanced ultrasonography. *Eur J Gastroenterol Hepatol.* 2007;19(1):3-14.
27. Dietrich CF, Mertens JC, Braden B, Schuessler G, Ott M, Ignee A. Contrast-enhanced ultrasound of histologically proven liver hemangiomas. *Hepatology.* 2007;45(5):1139-1145.
28. Lanka B, Jang HJ, Kim TK, Burns PN, Wilson SR. Impact of contrast-enhanced ultrasonography in a tertiary clinical practice. *J Ultrasound Med.* 2007;26(12):1703-1714.
29. Luo W, Numata K, Morimoto M, et al. Focal liver tumors: characterization with 3D perflubutane microbubble contrast agent-enhanced US versus 3D contrast-enhanced multidetector CT. *Radiology.* 2009;251(1):287-295.
30. Trillaud H, Bruel JM, Valette PJ, et al. Characterization of focal liver lesions with SonoVue-enhanced sonography: international multicenter-study in comparison to CT and MRI. *World J Gastroenterol.* 2009;15(30):3748-3756.
31. Ba-Ssalamah A, Uffmann M, Saini S, Bastati N, Herold C, Schima W. Clinical value of MRI liver-specific contrast agents: a tailored examination for a confident non-invasive diagnosis of focal liver lesions. *Eur Radiol.* 2009;19(2):342-357.
32. Hussain SM, Terkivatan T, Zondervan PE, et al. Focal nodular hyperplasia: findings at state-of-the-art MR imaging, US, CT, and pathologic analysis. *Radiographics.* 2004;24(1):3-17; discussion 18-19.
33. Marin D, Brancatelli G, Federle MP, et al. Focal nodular hyperplasia: typical and atypical MRI findings with emphasis on the use of contrast media. *Clin Radiol.* 2008;63(5):577-585.
34. Zech CJ, Grazioli L, Breuer J, Reiser MF, Schoenberg SO. Diagnostic performance and description of morphological features of focal nodular hyperplasia in Gd-EOB-DTPA-enhanced liver magnetic resonance imaging: results of a multicenter trial. *Invest Radiol.* 2008;43(7):504-511.
35. Kim JI, Lee JM, Choi JY, et al. The value of gadobenate dimeglumine-enhanced delayed phase MR imaging for characterization of hepatocellular nodules in the cirrhotic liver. *Invest Radiol.* 2008;43(3):202-210.
36. Lupescu IG, Capsa RA, Gheorghe L, Herlea V, Georgescu SA. Tissue specific MR contrast media role in the differential diagnosis of cirrhotic liver nodules. *J Gastrointestin Liver Dis.* 2008;17(3):341-346.
37. Chou CT, Chen YL, Su WW, Wu HK, Chen RC. Characterization of cirrhotic nodules with gadoxetic acid-enhanced magnetic resonance imaging: the efficacy of hepatocyte-phase imaging. *J Magn Reson Imaging.* 2010;32(4):895-902.
38. Chou CT, Chen YL, Wu HK, Chen RC. Characterization of hyperintense nodules on precontrast T1-weighted MRI: utility of gadoxetic acid-enhanced hepatocyte-phase imaging. *J Magn Reson Imaging.* 2011;33(3):625-632.
39. Chung WS, Kim MJ, Chung YE, et al. Comparison of gadoxetic acid-enhanced dynamic imaging and diffusion-weighted imaging for the preoperative evaluation of colorectal liver metastases. *J Magn Reson Imaging.* 2011;34(2):345-353.
40. Holzapfel K, Eiber MJ, Fingerle AA, Bruegel M, Rummeny EJ, Gaa J. Detection, classification, and characterization of focal liver lesions: Value of diffusion-weighted MR imaging, gadoxetic acid-enhanced MR imaging and the combination of both methods. *Abdom Imaging.* 2012;37(1):74-82.
41. Ichikawa T, Saito K, Yoshioka N, et al. Detection and characterization of focal liver lesions: a Japanese phase III, multicenter comparison between gadoxetic acid disodium-enhanced magnetic resonance imaging and contrast-enhanced computed tomography predominantly in patients with hepatocellular carcinoma and chronic liver disease. *Invest Radiol.* 2010;45(3):133-141.
42. Kim JE, Kim SH, Lee SJ, Rhim H. Hypervascular hepatocellular carcinoma 1 cm or smaller in patients with chronic liver disease: characterization with gadoxetic acid-enhanced MRI that includes diffusion-weighted imaging. *AJR Am J Roentgenol.* 2011;196(6):W758-765.
43. Kim YK, Kwak HS, Kim CS, Han YM. Detection and characterization of focal hepatic tumors: a comparison of T2-weighted MR images before and after the administration of gadoxectic acid. *J Magn Reson Imaging.* 2009;30(2):437-443.

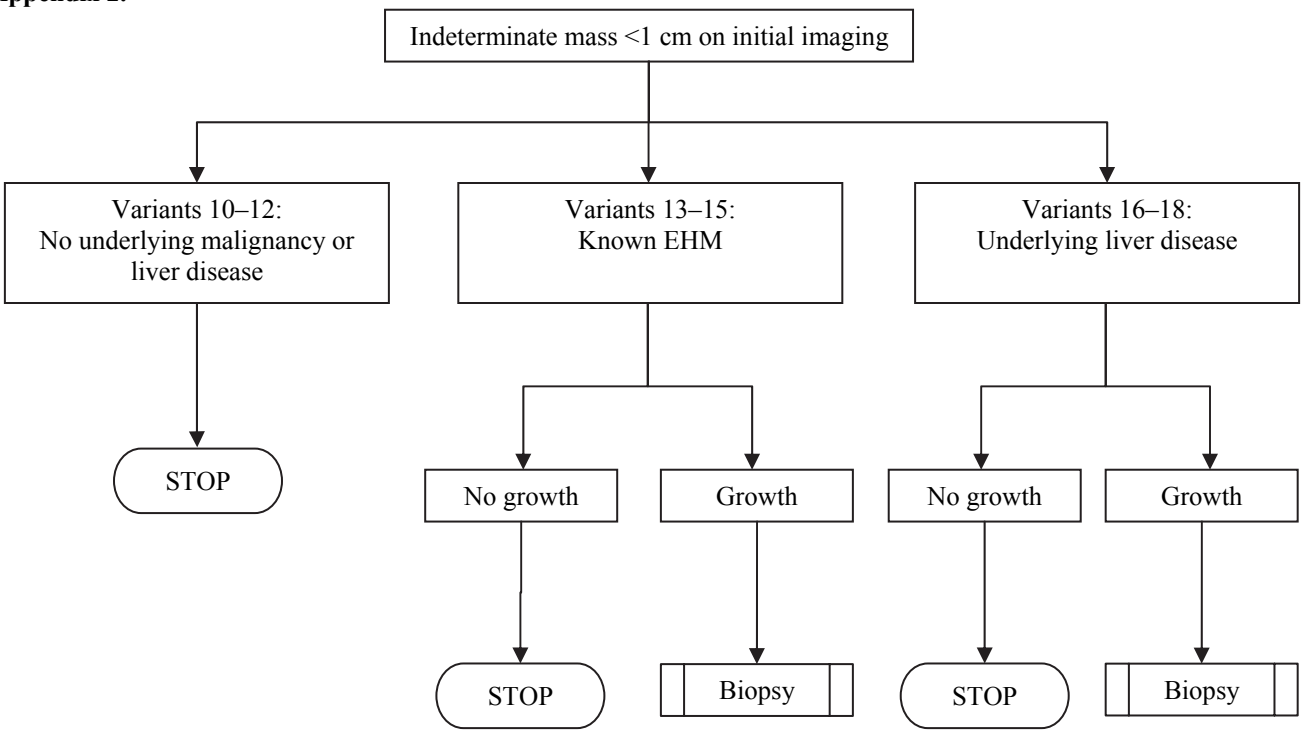
44. Purysko AS, Remer EM, Coppa CP, Obuchowski NA, Schneider E, Veniero JC. Characteristics and distinguishing features of hepatocellular adenoma and focal nodular hyperplasia on gadoxetate disodium-enhanced MRI. *AJR Am J Roentgenol.* 2012;198(1):115-123.
45. Cruite I, Schroeder M, Merkle EM, Sirlin CB. Gadoxetate disodium-enhanced MRI of the liver: part 2, protocol optimization and lesion appearance in the cirrhotic liver. *AJR Am J Roentgenol.* 2010;195(1):29-41.
46. Kim YK, Lee WJ, Park MJ, Kim SH, Rhim H, Choi D. Hypovascular hypointense nodules on hepatobiliary phase gadoxetic acid-enhanced MR images in patients with cirrhosis: potential of DW imaging in predicting progression to hypervascular HCC. *Radiology.* 2012;265(1):104-114.
47. Elsayes KM, Narra VR, Yin Y, Mukundan G, Lammle M, Brown JJ. Focal hepatic lesions: diagnostic value of enhancement pattern approach with contrast-enhanced 3D gradient-echo MR imaging. *Radiographics.* 2005;25(5):1299-1320.
48. Quinn SF, Benjamin GG. Hepatic cavernous hemangiomas: simple diagnostic sign with dynamic bolus CT. *Radiology.* 1992;182(2):545-548.
49. Semelka RC, Martin DR, Balci NC. Focal lesions in normal liver. *J Gastroenterol Hepatol.* 2005;20(10):1478-1487.
50. Caturelli E, Solmi L, Anti M, et al. Ultrasound guided fine needle biopsy of early hepatocellular carcinoma complicating liver cirrhosis: a multicentre study. *Gut.* 2004;53(9):1356-1362.
51. De Pauw FF, Francque SM, Bogers JP, et al. Fine needle trucut biopsy in focal liver lesions: a reliable and safe method in identifying the malignant nature of liver lesions. *Acta Gastroenterol Belg.* 2007;70(1):1-5.
52. Cantwell CP, Setty BN, Holalkere N, Sahani DV, Fischman AJ, Blake MA. Liver lesion detection and characterization in patients with colorectal cancer: a comparison of low radiation dose non-enhanced PET/CT, contrast-enhanced PET/CT, and liver MRI. *J Comput Assist Tomogr.* 2008;32(5):738-744.
53. Dromain C, de Baere T, Lumbroso J, et al. Detection of liver metastases from endocrine tumors: a prospective comparison of somatostatin receptor scintigraphy, computed tomography, and magnetic resonance imaging. *J Clin Oncol.* 2005;23(1):70-78.
54. Fernandez FG, Drebin JA, Linehan DC, Dehdashti F, Siegel BA, Strasberg SM. Five-year survival after resection of hepatic metastases from colorectal cancer in patients screened by positron emission tomography with F-18 fluorodeoxyglucose (FDG-PET). *Ann Surg.* 2004;240(3):438-447; discussion 447-450.
55. Kanematsu M, Kondo H, Goshima S, et al. Imaging liver metastases: review and update. *Eur J Radiol.* 2006;58(2):217-228.
56. Au-Yeung AW, Luk WH, Lo AX. Imaging features of colorectal liver metastasis in FDG PET-CT: a retrospective correlative analysis between CT attenuation and FDG uptake. *Nucl Med Commun.* 2012;33(4):403-407.
57. Coenegrachts K, ter Beek L, Haspeslagh M, Bipat S, Stoker J, Rigauts H. Comparison of respiratory-triggered T2-weighted turbo spin-echo imaging versus breath-hold T2-weighted turbo spin-echo imaging: distinguishing benign from malignant liver lesions in patients with colorectal cancer. *JBR-BTR.* 2009;92(4):195-201.
58. D'Souza M M, Sharma R, Mondal A, et al. Prospective evaluation of CECT and 18F-FDG-PET/CT in detection of hepatic metastases. *Nucl Med Commun.* 2009;30(2):117-125.
59. van Kessel CS, van Leeuwen MS, van den Bosch MA, et al. Accuracy of multislice liver CT and MRI for preoperative assessment of colorectal liver metastases after neoadjuvant chemotherapy. *Dig Surg.* 2011;28(1):36-43.
60. Bruegel M, Holzapfel K, Gaa J, et al. Characterization of focal liver lesions by ADC measurements using a respiratory triggered diffusion-weighted single-shot echo-planar MR imaging technique. *Eur Radiol.* 2008;18(3):477-485.
61. Taouli B, Koh DM. Diffusion-weighted MR imaging of the liver. *Radiology.* 2010;254(1):47-66.
62. Battal B, Kocaoglu M, Akgun V, et al. Diffusion-weighted imaging in the characterization of focal liver lesions: efficacy of visual assessment. *J Comput Assist Tomogr.* 2011;35(3):326-331.
63. Kele PG, van der Jagt EJ. Diffusion weighted imaging in the liver. *World J Gastroenterol.* 2010;16(13):1567-1576.
64. Lee HY, Lee JM, Kim SH, et al. Detection and characterization of focal hepatic lesions by T2-weighted imaging: comparison of navigator-triggered turbo spin-echo, breath-hold turbo spin-echo, and HASTE sequences. *Clin Imaging.* 2009;33(4):281-288.
65. Miller FH, Hammond N, Siddiqi AJ, et al. Utility of diffusion-weighted MRI in distinguishing benign and malignant hepatic lesions. *J Magn Reson Imaging.* 2010;32(1):138-147.

66. Onur MR, Cicekci M, Kayali A, Poyraz AK, Kocakoc E. The role of ADC measurement in differential diagnosis of focal hepatic lesions. *Eur J Radiol.* 2012;81(3):e171-176.
67. Papanikolaou N, Gourtsoyianni S, Yarmenitis S, Maris T, Gourtsoyiannis N. Comparison between two-point and four-point methods for quantification of apparent diffusion coefficient of normal liver parenchyma and focal lesions. Value of normalization with spleen. *Eur J Radiol.* 2010;73(2):305-309.
68. Sandrasegaran K, Akisik FM, Lin C, Tahir B, Rajan J, Aisen AM. The value of diffusion-weighted imaging in characterizing focal liver masses. *Acad Radiol.* 2009;16(10):1208-1214.
69. Xu PJ, Yan FH, Wang JH, Shan Y, Ji Y, Chen CZ. Contribution of diffusion-weighted magnetic resonance imaging in the characterization of hepatocellular carcinomas and dysplastic nodules in cirrhotic liver. *J Comput Assist Tomogr.* 2010;34(4):506-512.
70. Namasivayam S, Martin DR, Saini S. Imaging of liver metastases: MRI. *Cancer Imaging.* 2007;7:2-9.
71. 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):824-833.
72. Liu YI, Kamaya A, Jeffrey RB, Shin LK. Multidetector computed tomography triphasic evaluation of the liver before transplantation: importance of equilibrium phase washout and morphology for characterizing hypervascular lesions. *J Comput Assist Tomogr.* 2012;36(2):213-219.
73. Marin D, Nelson RC, Samei E, et al. Hypervascular liver tumors: low tube voltage, high tube current multidetector CT during late hepatic arterial phase for detection--initial clinical experience. *Radiology.* 2009;251(3):771-779.
74. Rimola J, Forner A, Reig M, et al. Cholangiocarcinoma in cirrhosis: absence of contrast washout in delayed phases by magnetic resonance imaging avoids misdiagnosis of hepatocellular carcinoma. *Hepatology.* 2009;50(3):791-798.
75. Sorrentino P, Tarantino L, D'Angelo S, et al. Validation of an extension of the international non-invasive criteria for the diagnosis of hepatocellular carcinoma to the characterization of macroscopic portal vein thrombosis. *J Gastroenterol Hepatol.* 2011;26(4):669-677.
76. Tarhan NC, Hatipoglu T, Ercan E, et al. Correlation of dynamic multidetector CT findings with pathological grades of hepatocellular carcinoma. *Diagn Interv Radiol.* 2011;17(4):328-333.
77. Arguedas MR, Chen VK, Eloubeidi MA, Fallon MB. Screening for hepatocellular carcinoma in patients with hepatitis C cirrhosis: a cost-utility analysis. *Am J Gastroenterol.* 2003;98(3):679-690.
78. Lauenstein TC, Salman K, Morreira R, et al. Gadolinium-enhanced MRI for tumor surveillance before liver transplantation: center-based experience. *AJR Am J Roentgenol.* 2007;189(3):663-670.
79. Silva AC, Evans JM, McCullough AE, Jatoi MA, Vargas HE, Hara AK. MR imaging of hypervascular liver masses: a review of current techniques. *Radiographics.* 2009;29(2):385-402.
80. Willatt JM, Hussain HK, Adusumilli S, Marrero JA. MR Imaging of hepatocellular carcinoma in the cirrhotic liver: challenges and controversies. *Radiology.* 2008;247(2):311-330.

Appendix 1.


Indeterminate mass >1 cm on initial imaging
Variants 1–3: No underlying malignancy or liver disease
Variants 4–6: Known EHM
Variants 7–9: Underlying liver disease
Further imaging
Biopsy or further imaging as necessary to stage and define more lesions
Further imaging to characterize
Defined Mass
Indeterminate
Defined Mass
Indeterminate
STOP
Biopsy
STOP
Biopsy

Appendix 2.


Indeterminate mass <1 cm on initial imaging
Variants 10–12: No underlying malignancy or liver disease
Variants 13–15: Known EHM
Variants 16–18: Underlying liver disease
STOP
No growth
Growth
No growth
Growth
STOP
Biopsy
STOP
Biopsy