Supplementary Material

MRI Image Acquisition

Hospital 1: Patients underwent MR scanning using a 1.5T scanner and an 8-channel abdominal coil (Optima MR360, GE Healthcare).

Hospital 2: Patients underwent MR scanning using a 3.0T scanner and an 16-channel abdominal coil (Discovery MR750, GE Healthcare).

Hospital 3: Patients underwent MR scanning using a 3.0T scanner and a 16-channel abdominal coil (Philips Ingenia).

Supplementary Table 1. Detailed scanner and scan parameters of Hospital 1.

Sequences	Image plane	TR/TE (msec)	FOV (mm)	Flip angle	Thickness (mm)	Matrix	Scanning order
T2WI	A	6000/85	420 × 420	160	8	512 × 512	2
T1WI	A	190/4.3	420 × 420	80	8	256 × 160	1
DWI	A	3650/75	420 × 420	90	8	200 × 200	3
AP	A	3.7/1.7	420 × 420	15	5	256 × 200	4
PVP	A	3.7/1.7	420× 420	15	5	256 × 200	5
DP	A	3.7/1.7	420 ×420	15	5	256 × 200	6

Supplementary Table 2. Detailed scanner and scan parameters of Hospital 2.

Sequences	Image plane	TR/TE (msec)	FOV (mm)	Flip angle	Thickness (mm)	Matrix	Scanning order
T2WI	A	6666/72	380 × 380	110	6	320 × 320	1
T1WI	A	3.7/1.7	400 × 400	12	6	512 × 512	2
DWI	A	7500/54	380 × 380	90	6	96 × 128	3
AP	A	3.7/2.2	360 × 360	12	5	512 × 512	4
PVP	A	3.7/2.2	360 × 360	12	5	512 × 512	5
DP	C	3.7/2.2	360 × 360	12	5	512 × 512	6

Supplementary Table 3. Detailed scanner and scan parameters of Hospital 3.

Sequences	Image plane	TR/TE (msec)	FOV (mm)	Flip angle	Thickness (mm)	Matrix	Scanning order
T2WI	A	6400/75	400 × 400	130	5	320 × 320	2
T1WI	A	3.8/1.6	400 × 400	17	4	320 × 320	1
DWI	A	7000/60	400 × 400	90	5	128× 128	3
AP	A	3.8/1.6	400 × 400	17	4	320 × 320	4
PVP	A	3.8/1.6	400 × 400	17	4	320 × 320	5
DP	A	3.8/1.6	400 × 400	17	4	320 × 320	6

Supplementary Table 4. The definition of LI-RADS MRI features.

LI-RADS features	Definition
MRI Tumor diameter(cm)	To measure the largest outer-edge-to-outer-edge dimension of an observation, it is important to consider the following guidelines: 1. Incorporate "Capsule" in Measurement: Ensure that the measurement includes any encapsulating "capsule" that may be present around the observation. 2. Select the Phase, Sequence, and Plane with Clearest Margins: When determining the dimensions, choose the phase, sequence, and imaging plane in which the margins of the observation are most clearly visible. 3. Avoid Measurements in the Arterial Phase (AP) or diffusion-weighted imaging (DWI): It is advisable not to measure in the AP or on DWI if the margins are distinctly visible in a different phase. This is important because measuring in the AP may lead to overestimation due to summation with periobservation enhancement. Additionally, measurements on DWI may not be reliable due to potential anatomic distortion.
Radiological capsule enhancement	Present Enhancing "Capsule": An enhancing capsule is characterized by a smooth, uniform, and sharp border that surrounds most (in the case of incomplete) or all (in the case of complete) of an observation. It is notably thicker or more prominent than the fibrotic tissue surrounding background nodules. This enhancing capsule is clearly visible as an enhancing rim in images acquired during the portal vein phase (PVP), delayed phase (DP), or transitional phase (TP). Absent (Non-Enhancing "Capsule"): In contrast, when referring to an absent or non-enhancing "capsule," there is no visible capsule appearance as an enhancing rim.
Restricted diffusion	The intensity on DWI should be significantly higher than the liver, not solely due to T2 shine-through, and the apparent diffusion coefficient (ADC) should be markedly lower than that of the liver.
Non-rim APHE	This refers to unequivocal enhancement, either wholly or partially, in the AP, which is greater in attenuation or intensity than that observed in the liver. The enhancing part must exhibit higher attenuation or intensity than the liver in the AP. This should be contrasted with the concept of rim arterial phase hyperenhancement (rim APHE).
Rim APHE	This represents a spatially defined subtype of APHE, characterized by the most pronounced AP enhancement in the periphery of the observation.
Nonperipheral "washout"	This refers to a nonperipheral, visually assessed reduction in enhancement, either wholly or partially, relative to composite liver tissue from an earlier to a later phase. This results in hypoenhancement during the extracellular phase, which occurs in the portal venous or delayed phase if an extracellular contrast agent (ECA) or gadobenate is administered. In the case of gadoxetate, this reduction in enhancement is seen during the portal venous phase.

Supplementary Table 5 The definition of Non-LI-RADS MRI features

Non-LI-RADS features	Definition
Tumor number	Only one lesion was solitary, and two or more lesions were multiple.
Shape	Tumors with a round or oval shape are categorized as regular, while those with other shapes, such as lobulated, star-like, or needle-like, are classified as irregular.
Margin	Nodular tumors with smooth boundary were smooth margin, non-nodular tumors with irregular contour and budding into the surrounding liver parenchyma were non-smooth margin.
Enhancement pattern	Typical enhancement meets the "wash in and wash out" enhancement, and the rest were typical;
Arterial Peritumoral enhancement	Defined as the enhancement outside the tumor boundary in the late stage of AP or early stage of PVP and extensive contact with the tumor edge, which becomes isointense during the DP.

Supplementary Table 6 Comparisons of patient characteristics in training, test, and validation sets

Characteristic	Training set (n = 177)			Test set (n = 78)		validation set (n = 54)	
	VETC negative (n=91)	VETC positive (n=86)	P	VETC negative (n=37)	VETC positive (n=41)	VETC negative (n=26)	VETC positive (n=28)
Clinical features							
Age	55.96±10.10	54.35±11.54	0.323	54.59±9.49	58.51±12.39	56.27±10.29	58.93±8.68
Gender			0.578				
Male	71(40.1%)	70(39.5%)		32(41.0%)	36(46.2%)	22(40.7%)	22(40.7%)
Female	20(11.3%)	16(9.0%)		5(6.4%)	5(6.4%)	4(7.4%)	6(11.1%)
Liver disease			0.750				
HAV	0(0.0%)	1(0.6%)		0(0%)	0(0.0%)	0(0.0%)	0(0.0%)
HBV	77(43.5%)	75(42.4%)		35(44.9%)	37(47.4%)	19(35.2%)	25(46.3%)
HCV	3(1.7%)	2(1.1%)		0(0.0%)	0(0.0%)	2(3.7%)	0(0.0%)
None	11(6.2%)	8(4.5%)		2(2.6%)	4(5.1%)	5(9.3%)	3(5.6%)
AFP-L3			0.886				
Negative	69(39.0%)	66(37.3%)		28(35.9%)	34(43.6%)	20(37.0%)	21(38.9%)
Positive	22(12.4%)	20(11.3%)		9(11.5%)	7(9.0%)	6(11.1%)	7(13.0%)
AFP_Lg10	1.07(0.49-2.05)	1.48(0.92-2.36)	0.009	1.10(0.64-1.85)	1.47(0.85-2.45)	1.23(0.69-1.90)	1.95(0.90-2.64)
PIVKA-II (mAU/mL)	50(27-194.05)	83(28-213.75)	0.635	41(24.5-135.5)	88(31-193.52)	58(27.75-321.5)	60(23-295.75)
CA199(U/mL)	12.6(7.6-21.7)	17.85(7.38-32.55)	0.003	16.7(10.6-27.6)	19.6(10.35-28.85)	18.66(9.44-29.35)	28.3(13.58-49.43)
CEA(ng/mL)	2.3(1.2-3.3)	2.6(1.6-3.53)	0.115	2.6(2.0-3.6)	2.5(1.6-4.1)	2.54(1.97-3.75)	2.15(1.54-3.88)
ALT(U/L)	27(20-38)	27(19-40.25)	0.355	24(18-35.36)	23(17-36.86)	26(19.75-49.50)	25.5(17.25-39.00)
AST(U/L)	25(20-32)	27.5(20.75-36.25)	0.834	20(17-31.5)	25(20.5-32.25)	27.5(21.5-37.5)	25(18.25-34.00)
TP(g/L)	69.27±5.26	69.65±5.41	0.631	69.14±5.70	68.36±5.85	67.90±5.99	66.86±4.74
ALB(g/L)	42.6(40.2-44.8)	42.55(39.58-45.15)	0.260	42.50(39.30-44.85)	41.1(38.35-44.65)	42.15(39.33-45.28)	40.5(38.65-43.73)
GLOB(g/L)	25.8(24-28.7)	27.45(24.2-29.9)	0.273	26.9(23.25-29.95)	26.4(22.6-29.5)	26.55(23.98-28.65)	25.5(23-27.7)
TBIL(μmol/L)	13.9(10.7-18.0)	14.6(11.775-18.075)	0.762	14.5(12.1-16.6)	15.4(11.10-20.55)	15.05(12.18-18.53)	12.25(8.0-18.25)
DBIL(μmol/L)	5.3(4.1-6.6)	5.85(4.2-7.2)	0.442	5.6(4.05-7.10)	6.0(4.5-7.85)	5.85(4.88-8.23)	5.1(3.75-7.33)
IBIL(μmol/L)	8.4(6.8-11.9)	8.9(6.975-10.8)	0.957	8.8(7.0-9.95)	9.6(6.9-12.95)	8.1(6.6-10.15)	7.05(4.28-11.15)
CHE(U/L)	7246.9(6102-8117)	7246.9(5886.3-7945.5)	0.254	6152(5086.5-7471.9)	6934(5669.5-7633)	5942(4974.8-7500.8)	7106(5691.8-8998.0)
CG(ug/ML)	1.9(0.8-4.7)	2.15(0.975-4.79)	0.483	2.0(1.15-5.70)	2.2(1.45-4.79)	2.1(1.58-2.53)	1.8(1.40-3.63)
TBA(μmol/L)	6.5(4.1-14.3)	8.2(4.9-13.83)	0.688	7.9(3.95-18.85)	10.4(6.35-17.05)	7.35(3.98-17.85)	8.85(4.28-19.83)
GGT(U/L)	37(22-66)	51(32.75-83.0)	0.130	44(22.5-99.5)	35(25.00-62.15)	38(22.0-103.0)	34.5(20.5-69.5)

AFU(U/L)	25(19-31)	26.82(24-30.5)	0.104	24(20.5-31.5)	26(22.0-29.0)	28.5(23.45-34.75)	26.35(22.75-31.75)
PLT(10^9/L)	138.08±58.015	133.59±63.391	0.622	138.43±63.22	117.83±49.18	142.42±59.16	117.68±61.23
PT(S)	11.6(11.3-12.4)	11.95(11.38-12.83)	0.233	11.7(11.05-12.6)	11.7(11.15-12.25)	11.5(11.08-12.45)	11.9(11.30-12.58)
APTT(S)	27.4(24.8-29.5)	27.8(25.08-31.20)	0.569	26.6(23.85-29.55)	27.8(25.15-30.6)	28.6(26.38-29.53)	28.9(26.53-30.75)
TT(S)	20.46±1.54	20.49±1.29	0.887	20.20±1.39	20.54±1.32	18.69±0.93	18.45±1.28
FBG(g/L)	2.0(1.79-32.43)	2.1(1.82-2.32)	0.581	2.06(1.87-2.42)	2.11(1.86-2.42)	2.28(1.11-2.58)	2.10(1.82-2.78)
CHOL(mmol/L)	3.87(3.31-4.16)	3.91(3.51-4.33)	0.230	3.91(3.52-4.51)	3.91(3.48-4.14)	3.92(3.22-4.42)	3.67(3.33-4.50)
TG(mmol/L)	1.13(0.8-1.36)	0.85(1.15-1.36)	0.648	1.2(0.95-1.38)	1.04(0.80-1.18)	1.04(0.85-1.61)	1.09(0.81-1.49)
HDL-C(mmol/L)	1.19(0.96-1.3)	1.22(1.02-1.43)	0.144	1.09(0.97-1.55)	1.22(1.11-1.41)	1.13(0.88-1.42)	1.13(0.94-1.45)
LDL-C(mmol/L)	2.46(1.98-2.73)	2.46(2.1-2.79)	0.768	2.42(2.16-2.85)	2.46(2.05-2.71)	2.32(1.93-2.77)	2.42(2.03-2.95)
HBsAg			0.621				
Negative	14(7.9%)	11(6.2%)		2(2.6%)	6(7.7%)	7(13.0%)	4(7.4%)
Positive	77(43.5%)	75(42.4%)		35(44.9%)	35(44.9%)	19(35.2%)	24(44.4%)
HBsAb			0.071				
Negative	76(42.9%)	81(45.8%)		36(46.2%)	37(47.4%)	20(37.0%)	25(46.3%)
Positive	15(8.5%)	5(2.8%)		1(1.3%)	4(5.1%)	6(11.1%)	3(5.6%)
HBeAg			0.676				
Negative	63(35.6%)	62(35.0%)		30(38.5%)	32(41.0%)	23(42.6%)	23(42.6%)
Positive	28(15.8%)	24(13.6%)		7(9.0%)	9(11.5%)	3(5.6%)	5(9.3%)
HBeAb			0.386				
Negative	44(24.9%)	36(20.3%)		10(12.8%)	13(16.7%)	6(11.1%)	6(11.1%)
Positive	47(26.6%)	50(28.2%)		27(34.6%)	28(35.9%)	20(37.0%)	22(40.7%)
HBcAb			0.608				
Negative	2(1.1%)	3(1.7%)		1(1.3%)	0(0.0%)	2(3.7%)	1(1.9%)
Positive	89(50.3%)	83(46.9%)		36(46.2%)	41(52.6%)	24(44.4%)	27(50.0%)
HBV/C-DNA			0.083				
<50IU/ml	55(31.1%)	37(20.9%)		20(25.6%)	23(29.5%)	15(27.8%)	17(31.5%)
50-10^3	10(5.6%)	17(9.6%)		8(10.3%)	7(9.0%)	6(11.1%)	3(5.6%)
10^3-10^5	14(7.9%)	13(7.3%)		4(5.1%)	5(6.4%)	3(5.6%)	4(7.4%)
>10^5	12(6.8%)	19(10.7%)		5(6.4%)	6(7.7%)	2(3.7%)	3(5.6%)
HCVAB			0.698				
Negative	88(49.7%)	84(47.5%)		37(47.4%)	41(52.6%)		
Positive	3(1.7%)	2(1.1%)		0(0.0%)	0(0.0%)		
MRI features							
Tumor diameter(cm)	2.151±0.59	2.185±0.56	0.689	2.089±0.59	2.083±0.62	2.371±0.60	2.086±0.60
Tumor number			0.894				
Solitary	82(46.3%)	78(44.1%)		33(42.3%)	38(48.7%)	26(48.1%)	25(46.3%)
Multiple	9(5.1%)	8(4.5%)		4(5.1%)	3(3.8%)	0(0.0%)	3(5.6%)

			p-value				
Shape			0.004				
Regular	54(30.5%)	32(18.1%)		17(21.8%)	15(19.2%)	22(40.7%)	15(27.8%)
Irregular	37(20.9%)	54(30.5%)		20(25.6%)	26(33.3%)	4(7.4%)	13(24.1%)
Margin			0.003				
Smooth	52(29.4%)	30(16.9%)		22(28.2%)	8(10.3%)	21(38.9%)	15(27.8%)
Non-smooth	39(22.0%)	56(31.6%)		15(19.2%)	33(42.3%)	5(9.3%)	13(24.1%)
Radiological capsule enhancement			0.231				
Complete	25(14.1%)	33(18.6%)		11(14.1%)	6(7.7%)	17(31.5%)	13(24.1%)
Incomplete	49(27.7%)	36(20.3%)		16(20.5%)	27(34.6%)	4(7.4%)	9(16.7%)
Absent	17(9.6%)	17(9.6%)		10(12.8%)	8(10.3%)	5(9.3%)	6(11.1%)
Restricted diffusion			0.276				
Present	88(49.7%)	80(45.2%)		36(46.2%)	35(44.9%)	25(46.3%)	28(51.9%)
Absent	3(1.7%)	6(3.4%)		1(1.3%)	6(7.7%)	1(1.9%)	0(0.0%)
Nonrim APHE			0.689				
Present	67(37.9%)	61(34.5%)		23(29.5%)	28(35.9%)	24(44.4%)	24(44.4%)
Absent	24(13.6%)	25(14.1%)		14(17.9%)	13(16.7%)	2(3.7%)	4(7.4%)
Rim APHE			0.037				
Absent	27(15.3%)	14(7.9%)		24(30.8%)	32(41.0%)	24(44.4%)	22(40.7%)
Present	64(36.2%)	72(40.7%)		13(16.7%)	9(11.5%)	2(3.7%)	6(11.1%)
Arterial peritumoral enhancement			<0.001				
Absent	83(46.9%)	52(29.4%)		34(43.6%)	27(34.6%)	22(40.7%)	15(27.8%)
Present	8(4.5%)	34(19.2%)		3(3.8%)	14(17.9%)	4(7.4%)	13(24.1%)
Nonperipheral"washout"			0.823				
Present	61(34.5%)	59(33.3%)		21(26.9%)	29(37.2%)	19(35.2%)	22(40.7%)
Absent	30(16.9%)	27(15.3%)		16(20.5%)	12(15.4%)	7(13.0%)	6(11.1%)
Enhancement pattern			0.832				
Typical	60(33.9%)	58(32.8%)		20(25.6%)	28(35.9%)	19(35.2%)	22(40.7%)
Atypical	31(17.5%)	28(15.8%)		17(21.8%)	13(16.7%)	7(13.0%)	6(11.1%)

Unless otherwise noted, Data are number of patients, with percentages in parentheses. Data are medians, with interquartile ranges in parenthesis. Data are means with standard deviations in parenthesis.

The p-value of the training set calculated by univariable logistic regression.

Abbreviations: VETC, vessels encapsulating tumor clusters; HBV/C-DNA, quantitation of hepatitis B virus genomic DNA; HBV, hepatitis B virus; HCV, hepatitis C virus; AFP, alpha-fetoprotein; PIVKA-II, protein induced by vitamin K absence or antagonist-II; GGT, gamma glutamyl transferase; AFU, α-fucosidase; PT, prothrombin time; CHOL, total cholesterol; CA199, carbohydrate antigen 199; CEA, carcinoembryonic antigen; ALT, alanine aminotransferase; AST, aspartate aminotransaminase; TP, total protein; TBIL, total bilirubin; DBIL, direct bilirubin; IBIL, indirect bilirubin; CEA, carcinoembryonic antigen; CHE, cholinesterase; CG, glycocholic acid; TBA, total bile acid; PLT, platelet count; APTT, activated partial thromboplastin time; TT, thrombin time; FBG, fibrinogen; TG, triglyceride; HDL, high density lipoprotein; LDL-C, low density lipoprotein; APHE, arterial phase hyperenhancement.