Supplemental materials

Table S1

MRI sequences and parameters

Sequences	T1-weighted IP and OP imaging	Dynamic T1-weighted 3D GRE	T2-weighted 2D FSE	Diffusion-weighted imaging†
Repetition time (ms)	81	3.55	2800	4900
Echo time (ms)	2.5/1.3	1.30	85	57
Flip angle (°)	9	9	120	90
Section thickness (mm)	3	3	3	5
Spacing (mm)	1	0	1	1
Matrix size	320×224	320×224	320×320	128×88
Field of view (mm^2)	380×296	380×296	380×380	380×261
Acquisition time (s)	20	12	RG	221
Fat suppression	No	Yes	Yes	Yes

MRI, magnetic resonance imaging; IP, in-phase; OP, opposed-phase; 3D, three-dimensional; GRE, gradient recall echo; 2D, two-dimensional; FSE, fast spin-echo; RG, respiratory gating.

†Images were acquired under free breath.

Table S2

Definitions of the evaluated MR imaging features

MRI feature	Definition
Tumor Size	Largest outer-edge-to-outer-edge dimension of a liver observation
ADC value	ROIs were delineated on the ADC map at the level of the tumor's maximum diameter. Necrotic, hemorrhagic, and artifactual regions were excluded based on corresponding T2-weighted and contrast-enhanced T1-weighted images. Each measurement

	was performed in triplicate, with the mean values used for subsequent analysis.
Tumor margin	Non-smooth tumor margin: presence of non-nodular tumors with irregular contour that had budding portion at the periphery
Marked diffusion restriction	Increased signal intensity of the liver observation at diffusion-weighted imaging in relative to the spleen, not solely attributable to T2-weighted imaging shine-through effect
Marked T2 hyperintensity	Signal intensity of the liver observation on T2 weighed-imaging markedly higher than liver and similar to bile ducts and other fluid-filled structures
Intralesional fat	The tumor demonstrates a slightly higher signal than liver tissue on T1-weighted in-phase images, and the signal is lost on T1-weighted out-of-phase images.
Targetoid restriction	Concentric pattern on DWI characterized by restricted diffusion in observation periphery with less restricted diffusion in observation center.
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.
Nonrim APHE	Nonrim-like enhancement of the liver observation in arterial phase unequivocally greater in whole or in part than liver
Internal artery	Presence of discrete arterial enhancement within the tumor
Nonperipheral "washout"	Nonperipheral visually assessed temporal reduction in enhancement of the liver observation in whole or in part relative to composite liver tissue from earlier

	to later phase resulting in hypoenhancement in the extracellular phase
PVP peritumoral hypo-enhancement	Presence of wedge-shaped or flame-like hypointense area adjacent to the tumor border on portal venous phase images
Tumor capsule	Complete: Presence of non-disrupted "capsule" in all imaging planes; Incomplete: Presence of disrupted "capsule" in all imaging planes
Intratumoral hemorrhage	The presence of ill-defined high signal within the tumor or around the tumor on T1-weighted images without the use of biopsy, trauma, or intervention. The signal does not disappear on T1 fat-suppressed or T2-weighted images.
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
Intralesional necrosis	The water-like signal is present within the tumor on T2-weighted images, with no enhancement on dynamic enhanced images, involving at least 20% of the tumor's largest cross-sectional diameter horizontally.
Tumor in vein	Presence of unequivocal enhancing soft tissue in vein
Peritumoral enhancement on AP	Detectable portion of crescent or polygonal shaped enhancement outside the tumor margin with broad contact to the tumor border in the arterial phase, becoming isointense with background liver parenchyma in the delayed phase.

Tumor hypointensity on HBP	Showing lower signal intensity than that of the surrounding liver.
Peritumoral hypointensity on HBP	Wedge-shaped or flame-like hypointense area of hepatic parenchyma located outside of the tumor margin on HBP
Extrahepatic metastasis	Extrahepatic metastasis includes distant metastasis or lymph node metastasis.
Hemorrhage and necrosis	The tumor has both intratumoral hemorrhage and necrosis.

ADC, apparent diffusion coefficient, ROIs, regions of interests, AP, arterial phase; PVP, portal venous phase; TP, transitional phase； IP, in-phase; OP, opposed-phase; HBP, hepatobiliary phase; APHE, arterial phase hyperenhancement; DWI, diffusion-weighted imaging; T2WI, T2-weighted imaging; T1WI, T1-weighted imaging.

Table S3

Baseline features among the training and validation datasets

Variable	Total (n = 111)	Training set (n = 77)	Validation set (n = 34)	p
Outcome, n (%)				0.201
Alive	90 (81.1)	60 (77.9)	30 (88.2)	
Death	21 (18.9)	17 (22.1)	4 (11.8)	
Survival time, Median (Q1, Q3)	61.0 (59.0, 63.0)	60.0 (59.0, 63.0)	61.0 (60.0, 63.5)	0.227
EFNA3, n (%)				1
Low expression	11 (9.9)	8 (10.4)	3 (8.8)	
High expression	100 (90.1)	69 (89.6)	31 (91.2)	
Age				0.519
≤60 yr	92 (82.9)	65 (84.4)	27 (79.4)	
>60 yr	19 (17.1)	12 (15.6)	7 (20.6)	
Sex				0.753
Female	12 (10.8)	9 (11.7)	3 (8.8)	
Male	99 (89.2)	68 (88.3)	31 (91.2)	
TBIL				0.11
≤17 μmol/L	94 (84.7)	68 (88.3)	26 (76.5)	
>17 μmol/L	17 (15.3)	9 (11.7)	8 (23.5)	
DBIL				0.038
≤6.8 μmol/L	91 (82.0)	67 (87.0)	24 (70.6)	

>6.8 μmol/L	20 (18.0)	10 (13.0)	10 (29.4)	
ALB				0.906
≤35 g/L	17 (15.3)	12 (15.6)	5 (14.7)	
>35 g/L	94 (84.7)	65 (84.4)	29 (85.3)	
ALT				0.373
≤40 U/L	75 (67.6)	50 (64.9)	25 (73.5)	
>40 U/L	36 (32.4)	27 (35.1)	9 (26.5)	
AST				0.311
≤35 U/L	54 (48.6)	35 (45.5)	19 (55.9)	
>35 U/L	57 (51.4)	42 (54.5)	15 (44.1)	
PIVKA-II				0.074
≤100 mAU/mL	48 (43.2)	29 (37.7)	19 (55.9)	
>100 mAU/mL	63 (56.8)	48 (62.3)	15 (44.1)	
AFP				0.139
≤400 ng/mL	81 (73.0)	53 (68.8)	28 (82.4)	
>400 ng/mL	30 (27.0)	24 (31.2)	6 (17.6)	
HBV infection				0.255
No	20 (18.0)	16 (20.8)	4 (11.8)	
Yes	91 (82.0)	61 (79.2)	30 (88.2)	
BCLC stage				0.517
0	1 (0.9)	0 (0.0)	1 (2.9)	
A	83 (74.8)	59 (76.6)	24 (70.6)	
B	22 (19.8)	15 (19.5)	7 (20.6)	
C	5 (4.5)	3 (3.9)	2 (5.9)	
Pathologic ES grade				1
Grade I/II	10 (9.0)	7 (9.1)	3 (8.8)	
Grade III/IV	101 (91.0)	70 (90.9)	31 (91.2)	
Number of tumors				0.337
Solitary	98 (88.3)	66 (85.7)	32 (94.1)	
Multiple	13 (11.7)	11 (14.3)	2 (5.9)	
VEGF				0.506
Negative	70 (63.1)	47 (61.0)	23 (67.6)	
Positive	41 (36.9)	30 (39.0)	11 (32.4)	
Inflammation score				0.311
≤5	57 (51.4)	42 (54.5)	15 (44.1)	
>5	54 (48.6)	35 (45.5)	19 (55.9)	
Fibrosis score				0.382
≤4	65 (58.6)	43 (55.8)	22 (64.7)	
>4	46 (41.4)	34 (44.2)	12 (35.3)	
MVI				0.32
M0	77 (69.4)	55 (71.4)	22 (64.7)	
M1	22 (19.8)	16 (20.8)	6 (17.6)	
M2	12 (10.8)	6 (7.8)	6 (17.6)	
Size				0.145

>5 cm	38 (34.2)	23 (29.9)	15 (44.1)	
≤5 cm	73 (65.8)	54 (70.1)	19 (55.9)	
Intratumoral fat				0.431
Absence	103 (92.8)	70 (90.9)	33 (97.1)	
Presence	8 (7.2)	7 (9.1)	1 (2.9)	
Intratumoral hemorrhage				0.243
Absence	89 (80.2)	64 (83.1)	25 (73.5)	
Presence	22 (19.8)	13 (16.9)	9 (26.5)	
Marked T2WI hyperintensity				0.243
No	45 (40.5)	34 (44.2)	11 (32.4)	
Yes	66 (59.5)	43 (55.8)	23 (67.6)	
Margin				0.824
Non-smooth	54 (48.6)	38 (49.4)	16 (47.1)	
Smooth	57 (51.4)	39 (50.6)	18 (52.9)	
Marked diffusion restriction				1
No	7 (6.3)	5 (6.5)	2 (5.9)	
Yes	104 (93.7)	72 (93.5)	32 (94.1)	
Targetoid diffusion restriction				1
No	105 (94.6)	73 (94.8)	32 (94.1)	
Yes	6 (5.4)	4 (5.2)	2 (5.9)	
Washout				0.398
No	18 (16.2)	14 (18.2)	4 (11.8)	
Yes	93 (83.8)	63 (81.8)	30 (88.2)	
Nonrim APHE				0.04
No	27 (24.3)	23 (29.9)	4 (11.8)	
Yes	84 (75.7)	54 (70.1)	30 (88.2)	
Peritumoral enhancement on AP				1
Absence	98 (88.3)	68 (88.3)	30 (88.2)	
Presence	13 (11.7)	9 (11.7)	4 (11.8)	
Intratumoral artery				0.298
Absence	70 (63.1)	51 (66.2)	19 (55.9)	
Presence	41 (36.9)	26 (33.8)	15 (44.1)	
Capsule				0.479
Incomplete	34 (30.6)	22 (28.6)	12 (35.3)	
Complete	77 (69.4)	55 (71.4)	22 (64.7)	
Peritumoral hypointensity on PVP				0.056
Absence	103 (92.8)	74 (96.1)	29 (85.3)	
Presence	8 (7.2)	3 (3.9)	5 (14.7)	
Nodule-in-nodule				0.368
Absence	105 (94.6)	74 (96.1)	31 (91.2)	
Presence	6 (5.4)	3 (3.9)	3 (8.8)	
Mosaic architecture				0.922
Absence	92 (82.9)	64 (83.1)	28 (82.4)	
Presence	19 (17.1)	13 (16.9)	6 (17.6)	

Tumor hypointensity on HBP				0.271
No	9 (8.1)	8 (10.4)	1 (2.9)	
Yes	102 (91.9)	69 (89.6)	33 (97.1)	
Peritumoral hypointensity on HBP				0.122
Absence	97 (87.4)	70 (90.9)	27 (79.4)	
Presence	14 (12.6)	7 (9.1)	7 (20.6)	
Targetoid TP or HBP appearance				0.175
Absence	105 (94.6)	71 (92.2)	34 (100.0)	
Presence	6 (5.4)	6 (7.8)	0 (0.0)	
Necrosis				0.649
Absence	72 (64.9)	51 (66.2)	21 (61.8)	
Presence	39 (35.1)	26 (33.8)	13 (38.2)	
Tumor in vein				0.386
Absence	96 (86.5)	68 (88.3)	28 (82.4)	
Presence	15 (13.5)	9 (11.7)	6 (17.6)	
Extrahepatic metastasis				1
Absence	107 (96.4)	74 (96.1)	33 (97.1)	
Presence	4 (3.6)	3 (3.9)	1 (2.9)	
Hemorrhage and necrosis				0.315
No	91 (82.0)	65 (84.4)	26 (76.5)	
Yes	20 (18.0)	12 (15.6)	8 (23.5)	
ADC, Median (Q1, Q3)	955.0 (783.5, 1025.5)	974.0 (788.0, 831.0)	912.5 (763.8, 991.5)	0.13

AFP, alpha-fetoprotein; PIVKA-II, Protein Induced by Vitamin K Absence or Antagonist-II; ALB, albumin; AST, aspartate aminotransferase; ALT, alanine transaminase; TBIL, total bilirubin; DBIL, direct bilirubin; BCLC, Barcelona Clinic Liver Cancer; ES, Edmondson–Steiner grade; MVI, microvascular invasion; VEGF, Vascular Endothelial Growth Factor; ADC, Apparent Diffusion Coefficient.

Table S4

Univariate Cox regression analysis results.

Variable	estimate	std. error	statistic	HR (95%CI)	p
EFNA3					
Low expression	0.000			reference	
High expression	-1.632	0.537	-3.038	0.196 (0.068, 0.560)	0.002
Age					
≤60 yr	0.000			reference	
>60 yr	-0.358	0.753	-0.476	0.699 (0.160, 3.056)	0.634
Sex					
Female	0.000			reference	
Male	18.226	5663.046	0.003	82330532.462(0.000, Inf)	0.997
TBIL					
≤17umol/L	0.000			reference	
>17umol/L	-0.000	0.753	-0.000	1.000 (0.229, 4.373)	1.000
DBIL					
≤6.8umol/L	0.000			reference	
>6.8umol/L	-18.254	5401.010	-0.003	0.000 (0.000, Inf)	0.997
ALB					
≤35g/L	0.000			reference	
>35g/L	-0.492	0.572	-0.860	0.612 (0.199, 1.876)	0.390
ALT					
≤40U/L	0.000			reference	
>40U/L	0.528	0.486	1.087	1.696 (0.654, 4.396)	0.277
AST					
≤35U/L	0.000			reference	
>35U/L	0.788	0.532	1.480	2.199 (0.774, 6.244)	0.139
PIVKA-II					
≤100 mAU/ml	0.000			reference	
>100 mAU/ml	-0.232	0.493	-0.470	0.793 (0.302, 2.084)	0.638
AFP					
≤400ng/ml	0.000			reference	
>400ng/ml	0.450	0.493	0.913	1.568 (0.597, 4.120)	0.361
HBV infection					
No	0.000			reference	
Yes	0.242	0.636	0.380	1.274 (0.366, 4.433)	0.704
BCLC stage					
0	0.000			reference	
A	17.109	5785.323	0.003	26940745.631(0.000, Inf)	0.998
B	16.924	5785.323	0.003	22386655.458(0.000, Inf)	0.998

C		0.000			
Pathologic ES grade					
Grade I/II	0.000			reference	
Grade III/IV	0.475	1.031	0.461	1.608 (0.213, 12.128)	0.645
Tumor number					
Solitary	0.000			reference	
Multiple	-0.258	0.753	-0.343	0.772 (0.177, 3.378)	0.732
VEGF					
Negative	0.000			reference	
Positive	-0.126	0.508	-0.248	0.882 (0.326, 2.385)	0.804
Inflammation score					
≤5	0.000			reference	
>5	0.044	0.486	0.091	1.045 (0.403, 2.709)	0.928
Fibrosis score					
≤4	0.000			reference	
>4	-0.110	0.493	-0.224	0.896 (0.341, 2.353)	0.823
MVI					
M0	0.000			reference	
M1	0.548	0.539	1.016	1.730 (0.601, 4.980)	0.310
M2	-0.155	1.045	-0.149	0.856 (0.111, 6.632)	0.882
Size					
≤5 cm	0.000			reference	
>5 cm	0.348	0.508	0.685	1.416 (0.523, 3.828)	0.494
Intratumoral fat					
Absence	0.000			reference	
Presence	0.456	0.753	0.606	1.578 (0.361, 6.906)	0.544
Intratumoral hemorrhage					
Absence	0.000			reference	
Presence	0.985	0.533	1.848	2.678 (0.942, 7.610)	0.065
Marked T2WI hyperintensity					
No	0.000			reference	
Yes	-0.461	0.486	-0.949	0.630 (0.243, 1.634)	0.342
Margin					
Non-smooth	0.000			reference	
Smooth	-1.006	0.533	-1.889	0.366 (0.129, 1.039)	0.059
Marked diffusion restriction					
No	0.000			reference	

Yes	0.087	1.031	0.084	1.091 (0.145, 8.229)	0.933
Targetoid diffusion restriction					
No	0.000			reference	
Yes	1.134	0.754	1.503	3.109 (0.709, 13.641)	0.133
Washout					
No	0.000			reference	
Yes	0.001	0.636	0.002	1.001 (0.288, 3.485)	0.998
Nonrim APHE					
No	0.000			reference	
Yes	-0.906	0.486	-1.863	0.404 (0.156, 1.048)	0.063
Peritumoral enhancement on AP					
Absence	0.000			reference	
Presence	0.595	0.637	0.935	1.814 (0.521, 6.315)	0.350
Intratumoral artery					
Absence	0.000			reference	
Presence	0.148	0.508	0.291	1.159 (0.429, 3.136)	0.771
Capsule					
Incomplete	0.000			reference	
Complete	-0.421	0.508	-0.830	0.656 (0.243, 1.775)	0.406
Peritumoral hypointensity on PVP					
Absence	0.000			reference	
Presence	1.953	0.759	2.575	7.053 (1.595, 31.193)	0.010
Nodule-in-nodule					
Absence	0.000			reference	
Presence	0.455	1.031	0.442	1.577 (0.209, 11.904)	0.659
Mosaic architecture					
Absence	0.000			reference	
Presence	0.126	0.636	0.198	1.134 (0.326, 3.946)	0.843
Tumor hypointensity on HBP					
No	0.000			reference	
Yes	-0.629	0.636	-0.989	0.533 (0.153, 1.856)	0.323
Peritumoral hypointensity on HBP					
Absence	0.000			reference	
Presence	0.468	0.753	0.621	1.596 (0.365, 6.985)	0.534
Targetoid TP or HBP appearance					
Absence	0.000			reference	
Presence	-0.397	1.031	-0.385	0.673 (0.089, 5.072)	0.700
Necrosis					

Absence	0.000			reference	
Presence	0.696	0.486	1.431	2.005 (0.773, 5.200)	0.152
Tumor in vein					
Absence	0.000			reference	
Presence	1.088	0.572	1.901	2.969 (0.967, 9.119)	0.057
Extrahepatic metastasis					
Absence	0.000			reference	
Presence	1.910	0.758	2.519	6.754 (1.527, 29.864)	0.012
Hemorrhage and necrosis					
No	0.000			reference	
Yes	1.117	0.533	2.095	3.055 (1.074, 8.686)	0.036
ADC	0.000	0.001	0.357	1.000 (0.998, 1.002)	0.721

AFP: alpha-fetoprotein; PIVKA-II: Protein Induced by Vitamin K Absence or Antagonist-II; ALB: albumin; AST: aspartate aminotransferase; ALT: alanine transaminase; TBIL: total bilirubin; DBIL: direct bilirubin; BCLC: Barcelona Clinic Liver Cancer; ES: Edmondson–Steiner grade; MVI: microvascular invasion; VEGF: Vascular Endothelial Growth Factor; ADC: Apparent Diffusion Coefficient.