**Data Supplement Content**

**Supplementary Fig. 1** Patients recruitment and study design.

**Supplementary Fig. 2** Performance of intratumoral radiomic signature for predicting the recurrence risk in the training, prospective-retrospective validation and external validation cohorts.

**Supplementary Fig. 3** Performance of peritumoral radiomic signature for predicting the recurrence risk in the training, prospective-retrospective validation and external validation cohorts.

**Supplementary Fig. 4** Performance of intratumoral-peritumoral radiomic signature for predicting the recurrence risk in different molecular subtype.

**Supplementary Fig. 5** Recurrence-free survival according to treatment (adjuvant chemotherapy vs. neoadjuvant chemotherapy) in radiomic-clinical signature-based risk groups.

**Supplementary Fig. 6** Recurrence-free survival according to St Gallen risk categories in T1N0M0 stage, HR-positive and Her2-negative status patients.

**Supplementary Table 1** Information of four institutions in this study.

**Supplementary Table 2** Univariate analysis of clinicopathological characteristics with recurrence-free survival.

**Supplementary Table 3** The performance of each signature for recurrence-free survival prediction.

**Supplementary Table 4** Multivariate analysis of radiomic signature and clinicopathological characteristics with recurrence-free survival in the training cohort.

**Supplementary Table 5** Magnetic resonance imaging scanning parameters for the patients.

**Supplementary Table 6** Essential radiomic features and formula composition.

**Supplementary 1** Magnetic resonance imaging acquisition.

**Supplementary 2** Radiomic feature extraction.

**Supplementary Fig. 1** Patients recruitment and study design.**手机屏幕截图

描述已自动生成**

A total of 1,084 patients with preoperative magnetic resonance imaging from four institutions were enrolled in this study to construct and validate signatures for predicting the recurrence risk. MRI, Magnetic resonance imaging; T1+C, contrast-enhanced T1-weighted imaging; T2WI, T2-weighted imaging; DWI-ADC, diffusion-weighted imaging quantitatively measured apparent diffusion coefficients.

**Supplementary Fig. 2** Performance of the intratumoral radiomic signature for predicting the recurrence risk in the training, prospective-retrospective validation and external validation cohorts.

**地图的截图

描述已自动生成**

Kaplan-Meier curves of RFS according to the intratumoral radiomic signature in the (A) training cohort, (B) prospective-retrospective validation cohort, and (C) external validation cohort. ROC curves and 1-, 2-, 3-year AUCs were used to assess the prognostic accuracy of the intratumoral radiomic signature in the (D) training cohort, (E) prospective-retrospective validation cohort, and (F) external validation cohort. P values were calculated using the unadjusted log-rank test and hazard ratios were calculated by a univariate Cox regression analysis. RFS, recurrence-free survival; HR, hazard ratio; CI, confidence interval; ROC, receiver operating characteristic; AUC, area under the receiver operating characteristics curve.

**Supplementary Fig. 3** Performance of the peritumoral radiomic signature for predicting the recurrence risk in the training, prospective-retrospective validation and external validation cohorts.

****

Kaplan-Meier curves of RFS according to the peritumoral radiomic signature in the (A) training cohort, (B) prospective-retrospective validation cohort, and (C) external validation cohort. ROC curves and 1-, 2-, 3-year AUCs were used to assess the prognostic accuracy of the peritumoral radiomic signature in the (D) training cohort, (E) prospective-retrospective validation cohort, and (F) external validation cohort. P values were calculated using the unadjusted log-rank test and hazard ratios were calculated by a univariate Cox regression analysis. RFS, recurrence-free survival; HR, hazard ratio; CI, confidence interval; ROC, receiver operating characteristic; AUC, area under the receiver operating characteristics curve.

**Supplementary Fig. 4** Performance of the intratumoral-peritumoral radiomic signature for predicting the recurrence risk in different molecular subtype.

社交网络的地图

描述已自动生成

Kaplan-Meier curves of RFS according to the intratumoral-peritumoral radiomic signature in the subgroups of (A) Luminal A, (B) Luminal B, (C) Her2-positive, and (D) Triple negative patients. P values were calculated using the unadjusted log-rank test. RFS, recurrence-free survival; HR, hazard ratio; CI, confidence interval; Her2, human epidermal growth factor receptors 2.

**Supplementary Fig. 5** Recurrence-free survival according to treatment (neoadjuvant chemotherapy vs. adjuvant chemotherapy) in radiomic-clinical signature-based risk groups.

**地图的截图

描述已自动生成**

Kaplan-Meier curves of RFS according to treatment in the (A) low-risk and (B) high-risk Luminal subtype patients. P values were calculated using the unadjusted log-rank test. RFS, recurrence-free survival; NAC, neoadjuvant chemotherapy; AC, adjuvant chemotherapy.

**Supplementary Fig. 6** Recurrence-free survival according to St Gallen risk categories in T1N0M0 stage, HR-positive and Her2-negative status patients.

**手机屏幕截图

描述已自动生成**

P values were calculated using the unadjusted log-rank test. HR, hormone receptors; Her2, human epidermal growth factor receptors 2.

|  |  |  |
| --- | --- | --- |
| **Supplementary Table 1** Information of four institutions in this study. | | |
| Institution | Investigator in Charge | No. of Patients Enrolled |
| Sun Yat-Sen Memorial Hospital | Herui Yao | 564 |
| Sun Yat-Sen University Cancer Center | Chuanmiao Xie | 340 |
| Tungwah Hospital of Sun Yat-Sen University | Jie Ouyang | 81 |
| Shunde Hospital of Southern Medical University | Qiugen Hu | 99 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Supplementary Table 2** Univariate analysis of clinicopathological characteristics with recurrence-free Survival. | | | | |
|  |  | | Training cohort |  |
| Characteristic | No. of patients (n) | | HR (95%CI) | *P* value |
| Age, years |  | |  |  |
| ＜40 | 132 | | ref |  |
| ≥ 40 | 667 | | 0.838 (0.402,1.748) | .640 |
| Number of tumors |  | |  |  |
| 1 | 701 | | ref |  |
| ＞1 | 97 | | 3.037 (1.531,6.025) | .001 |
| Histological grade |  | |  |  |
| Grade 1-2(low-intermediate) | 417 | | ref |  |
| Grade 3(high) | 380 | | 3.816 (1.879,7.749) | < .001 |
| Pathological T stage |  | |  |  |
| T1 | 410 | | ref |  |
| T2-4 | 389 | | 1.395 (0.768,2.534) | .270 |
| Pathological N stage |  | |  |  |
| N0 | 475 | | ref |  |
| N1-3 | 324 | | 3.468 (1.837,6.549) | < .001 |
| Pathological TNM stage |  | |  |  |
| I-II | 675 | | ref |  |
| III | 124 | | 4.355 (2.385,7.954) | < .001 |
| ER status |  | |  |  |
| Negative | 115 | | ref |  |
| Positive | 680 | | 0.906 (0.404,2.034) | .810 |
| PR status |  | |  |  |
| Negative | 218 | | ref |  |
| Positive | 577 | | 0.458 (0.252,0.833) | .009 |
| HR status |  | |  |  |
| Negative | 109 | | ref |  |
| Positive | 686 | | 0.818 (0.364,1.836) | .630 |
| Her2 status |  | |  |  |
| Negative | 532 | | ref |  |
| Positive | 236 | | 1.444 (0.782,2.665) | .240 |
| Ki67 expression |  | |  |  |
| ＜30 | 407 | | ref |  |
| ≥30 | 388 | | 2.899 (1.509,5.569) | .001 |
| Molecular Subtype |  | |  |  |
| Luminal | 686 | | ref |  |
| Non-luminal | 107 | 1.246 (0.555,2.797) | | .590 |
| Abbreviations: TNM, tumor–node–metastasis; Her2, human epidermal growth factor receptors 2; ER, estrogen receptor; PR, progesterone receptors; HR, hormone receptors; Ki67, [proliferation marker protein Ki-67](https://www.ncbi.nlm.nih.gov/protein/P46013.2). | | | | |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Supplementary Table 3** The performance of each signature for recurrence-free survival prediction. | | | | | | | | | | |
| Signature | Signature Performance | Signature Building | | Cox Regression | | | | | | |
| Cohort | | Intratumoral Radiomic Signature | | |  | Peritumoral Radiomic Signature | | |
| Training Cohort | Prospective-  retrospective Validation Cohort | External Validation Cohort |  | Training Cohort | Prospective-  retrospective Validation Cohort | External Validation Cohort |
| T1+C sequence radiomic signature |  | |  |  | | |  |  | | |
|  | No. of patients (n) | |  | 785 | 103 | 169 |  | 785 | 103 | 169 |
|  | 1-year AUC | |  | 0.89 | 0.77 | 0.86 |  | 0.83 | 0.65 | 0.51 |
|  | 2-year AUC | |  | 0.81 | 0.75 | 0.77 |  | 0.73 | 0.70 | 0.54 |
|  | 3-year AUC | |  | 0.76 | 0.80 | 0.74 |  | 0.59 | 0.56 | 0.54 |
| T2WI sequence radiomic signature |  | |  |  | | |  |  | | |
|  | n | |  | 714 | 103 | 169 |  | 714 | 103 | 169 |
|  | 1-year AUC | |  | 0.76 | 0.75 | 0.82 |  | 0.82 | 0.61 | 0.88 |
|  | 2-year AUC | |  | 0.78 | 0.71 | 0.63 |  | 0.77 | 0.66 | 0.89 |
|  | 3-year AUC | |  | 0.81 | 0.73 | 0.55 |  | 0.72 | 0.76 | 0.83 |
| DWI-ADC sequence radiomic signature |  | |  |  | | |  |  | | |
|  | n | |  | 473 | 99 | 169 |  | 473 | 99 | 169 |
|  | 1-year AUC | |  | 0.87 | 0.59 | 0.54 |  | 0.93 | 0.71 | 0.70 |
|  | 2-year AUC | |  | 0.83 | 0.67 | 0.56 |  | 0.91 | 0.54 | 0.73 |
|  | 3-year AUC | |  | 0.88 | 0.84 | 0.60 |  | 0.95 | 0.67 | 0.74 |

Abbreviations: AUC, area under the receiver operating characteristics curve; T1+C, contrast-enhanced T1-weighted imaging; T2WI, T2-weighted imaging; DWI-ADC, diffusion-weighted imaging quantitatively measured apparent diffusion coefficients.

|  |  |  |
| --- | --- | --- |
| **Supplementary Table 4** Multivariate analysis of intratumoral-peritumoral radiomic signature and clinicopathological characteristics with recurrence-free survival in the training cohort. | | |
| Signature | Multivariate Analysis | |
| HR (95%CI) | *P* value |
| Intratumoral-peritumoral radiomic  signature (high-risk/low-risk) | 2.73 (2.07-3.61) | < .001 |
| Number of tumor (multiple/single) | 2.47 (1.01-6.07) | .048 |
| Histological grade (high-grade/low-grade) | 2.95 (1.15-7.55) | .024 |
| Pathological TNM stage  (pTNM III/pTNM I-II) | 2.95 (1.19-7.30) | .020 |
| Ki67 expression (≥30/<30) | 2.95 (1.09-7.96) | .033 |
| Abbreviations: HR, Hazard ratio; CI, confidence interval; TNM, tumor–node–metastasis; Ki67, [proliferation marker protein Ki-67](https://www.ncbi.nlm.nih.gov/protein/P46013.2). | | |

**Supplementary Table 5** Magnetic resonance imaging scanning parameters for the patients.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hospital | Scanner | Sequence | TR/TE  (ms) | FOV  (mm) | Matrix | Slice Thickness (mm) | Slice Gap  (mm) | Slices | Flip Angle | Acquisition  Time (min) | Scans |
| SYSMH | Philips 1.5T  (Achieva) | T2WI | 4000/60 | 337×240 | 400×318 | 3 | 0 | 55 | 90° | 4min |  |
| DWI-ADC | 7439/53 | 363×340 | 360×301 | 3 | 0 | 55 | 90° | 4min35s |  |
| T1+C | 3.3/1.54 | 320×250 | 217×172 | 1 | 0 | 55 | 10° | 7min | 55 |
| Philips 3.0T  (Ingenia) | T2WI | 4000/60 | 337×240 | 400×318 | 3 | 0 | 55 | 90° | 4min |  |
| DWI-ADC | 7439/53 | 363×340 | 360×301 | 3 | 0 | 55 | 90° | 4min35s |  |
| T1+C | 3.3/1.54 | 320×250 | 217×172 | 1 | 0 | 55 | 10° | 7min | 55 |
| Siemens 1.5T  (Avanto) | T2WI | 2760/107 | 350×350 | 320×224 | 5 | 1 | 30 | 150° | 2min46s |  |
| DWI-ADC | 5400/119 | 400×252 | 200×170 | 6 | 1.8 | 20 | 180° | 2min34s |  |
| T1+C | 4.95/2.2 | 380×269 | 288×216 | 3 | 0.6 | 48-72 | 10° | 5-7min | 50/70 |
| Siemens 3.0T  (Skyra) | T2WI | 7600/75 | 340×340 | 448×358 | 4 | 0.8 | 35 | 116° | 3min42s |  |
| DWI-ADC | 7620/64 | 360×310 | 192×192 | 4 | 0.8 | 35 | 180° | 1min54s |  |
| T1+C | 3.25/1.22 | 380×327 | 256×218 | 2.5 | 0.5 | 48-72 | 10° | 5-7min | 50/70 |
| SYSUCC | United Imaging 3.0T  (China) | T2WI | 3600/74.34 | 340×340 | 336×335 | 5 | 1 | 24 | 90° | 3min05s |  |
| DWI-ADC | 3597/67.2 | 350×350 | 350×190 | 6 | 1 | 24 | 90° | 1min33s |  |
| T1+C | 4.3/1.99 | 340×340 | 336×335 | 0.67 | 0 | 204 | 10° | 9min58s | 8 |
| GE 3.0T  (USA) | T2WI | 3912/107.64 | 380×380 | 416×256 | 5 | 1 | 28 | 111° | 1min59s |  |
| DWI-ADC | 4168/60.2 | 380×380 | 128×160 | 5 | 1 | 48 | - | 1min40s |  |
| T1+C | 4.3/1.7 | 360×360 | 256×320 | 1 | 0 | 204 | 5° | 9min50s | 8 |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hospital | Scanner | Sequence | TR/TE  (ms) | FOV  (mm) | Matrix | Slice Thickness (mm) | Slice Gap  (mm) | Slices | Flip Angle | Acquisition  Time (min) | Scans |
| SYSUTH | Philips 1.5T  (Achieva) | T2WI | 3400/90 | 260×320 | 348×299 | 3 | 0.3 | 44 | 120° | 4min4s |  |
| DWI-ADC | 2000/103 | 320×320 | 160×160 | 5 | 1 | 32 | 90° | 1min36s |  |
| T1+C | 5.4/2.4 | 300×320 | 300×320 | 1 | 0 | 300 | 15° | 7min2s | 6 |
| Philips 3.0T  (Ingenia) | T2WI | 4495/70 | 280×340 | 332×377 | 3 | 0 | 52 | 90° | 3min53s |  |
| DWI-ADC | 7011/67 | 320×340 | 148×153 | 4 | 1 | 30 | 90° | 1min24s |  |
| T1+C | 4.8/2.1 | 280×340 | 280×339 | 1 | 0 | 300 | 12° | 6min59s | 6 |
| SMUSH | Philips 1.5T  (Achieva) | T2WI | 4518/70 | 320×260 | 256×159 | 4 | 0.07 | 36 | 120° | 3min19s |  |
| DWI-ADC | 5837/67 | 365×221 | 124×73 | 3 | 1 | 36 | 90° | 3min59s |  |
| T1+C | 6.0/2.9 | 350×255 | 252×243 | 2 | 1 | 150 | 10° | 6min42s | 9 |
| Siemens 3.0T  (Skyra) | T2WI | 4290/78 | 128×332 | 332×128 | 4 | 1 | 30 | 180° | 1min22s |  |
| DWI-ADC | 6560/49 | 340×172 | 66×130 | 4 | 0.8 | 37 | 180° | 3min51s |  |
| T1+C | 5.59/1.96 | 154×338 | 562×256 | 2 | 0.4 | 72 | 10° | 7min15s | 6 |

Abbreviations: FOV, field of view; TR, repetition time; TE, echo time; T1+C, contrast-enhanced T1-weighted imaging; T2WI, T2-weighted imaging; DWI-ADC, diffusion-weighted imaging quantitatively measured apparent diffusion coefficients.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Supplementary Table 6** Essential radiomic features and formula composition. | | | | |
| **Signature** | **Feature Name** | **Coefficient** | | |
| **T1+C sequence intratumoral signature** | | | | | |
|  | | wavelet-HHH-firstorder-Median | | 0.737 | |
|  | | wavelet-LHH-gldm-DependenceNonUniformity | | 0.130 | |
|  | | wavelet-HLH-glszm-LargeAreaEmphasis | | -0.270 | |
|  | | wavelet-HLL-glszm-LargeAreaHighGrayLevelEmphasis | | -0.190 | |
|  | | wavelet-HLH-glszm-LargeAreaHighGrayLevelEmphasis | | 0.197 | |
|  | | wavelet-HLH-firstorder-Median | | -0.259 | |
|  | | wavelet-HHH-gldm-DependenceNonUniformity | | -0.162 | |
|  | | wavelet-HHH-ngtdm-Busyness | | 0.065 | |
|  | | wavelet-LHH-glcm-MCC | | -0.270 | |
|  | | wavelet-LHL-glcm-MCC | | -0.326 | |
|  | | wavelet-LLH-gldm-GrayLevelNonUniformity | | 1.391 | |
|  | | wavelet-LLH-glrlm-GrayLevelNonUniformity | | -1.397 | |
|  | | wavelet-LHL-glszm-LargeAreaHighGrayLevelEmphasis | | 0.323 | |
|  | | wavelet-HLH-ngtdm-Coarseness | | -6982.463 | |
| **T2WI sequence intratumoral signature** | | | | | |
|  | | wavelet-HLH-glcm-MCC | | -1.607 | |
|  | | wavelet-HLL-firstorder-Kurtosis | | 0.042 | |
|  | | wavelet-HHH-glrlm-ShortRunEmphasis | | 11.822 | |
|  | | wavelet-HHH-glrlm-RunEntropy | | 6.496 | |
|  | | wavelet-HHH-glrlm-LongRunEmphasis | | 1.566 | |
|  | | wavelet-HHH-glcm-ClusterTendency | | -0.684 | |
|  | | wavelet-HHH-glrlm-LongRunLowGrayLevelEmphasis | | -2.082 | |
|  | | wavelet-HHH-glcm-DifferenceAverage | | 0.697 | |
|  | | wavelet-HHH-gldm-LargeDependenceLowGrayLevelEmphasis | | 1.935 | |
|  | | wavelet-LHH-glrlm-LongRunEmphasis | | -0.125 | |
|  | | wavelet-LLL-ngtdm-Coarseness | | -21.870 | |
|  | | wavelet-HLL-firstorder-Skewness | | -1.977 | |
|  | | wavelet-HHH-ngtdm-Complexity | | -0.062 | |
|  | | wavelet-HLH-gldm-DependenceNonUniformity | | -3.824 | |
|  | | wavelet-HLH-glrlm-LongRunEmphasis | | -0.303 | |
|  | | wavelet-HLL-glszm-ZoneVariance | | 8.556 | |
|  | | wavelet-HLL-gldm-GrayLevelNonUniformity | | -0.082 | |
|  | | wavelet-HHH-glrlm-RunPercentage | | 2.038 | |
|  | | wavelet-LHH-gldm-LargeDependenceEmphasis | | 1.108 | |
|  | | wavelet-HLH-ngtdm-Busyness | | -1.053 | |
|  | | wavelet-HLH-glrlm-GrayLevelNonUniformity | | -7.805 | |
|  | | wavelet-LHL-glrlm-GrayLevelNonUniformity | | -0.696 | |
|  | | wavelet-HLL-gldm-LargeDependenceHighGrayLevelEmphasis | | -0.143 | |
|  | | wavelet-HHL-gldm-LargeDependenceEmphasis | | -0.414 | |
|  | | wavelet-HHL-glszm-LargeAreaHighGrayLevelEmphasis | | 0.032 | |
| **Signature** | | **Feature Name** | | **Coefficient** | |
|  | | wavelet-LLH-glrlm-GrayLevelNonUniformity | | 6.814 | |
|  | | wavelet-LLH-gldm-DependenceNonUniformity | | 2.003 | |
|  | | wavelet-LLL-glrlm-RunPercentage | | -0.347 | |
|  | | wavelet-HLL-glszm-LargeAreaEmphasis | | -8.184 | |
|  | | wavelet-HLH-gldm-GrayLevelNonUniformity | | 3.442 | |
| **DWI-ADC sequence intratumoral signature** | | | | | |
|  | | wavelet-HHL-gldm-LargeDependenceHighGrayLevelEmphasis | | | 0.385 |
|  | | wavelet-LHH-gldm-DependenceNonUniformity | | | -0.569 |
|  | | wavelet-HHL-glrlm-LongRunHighGrayLevelEmphasis | | | -0.029 |
|  | | wavelet-LHH-glrlm-RunLengthNonUniformity | | | 0.684 |
|  | | wavelet-LHL-glszm-LargeAreaLowGrayLevelEmphasis | | | 0.281 |
|  | | wavelet-HLH-firstorder-TotalEnergy | | | 0.243 |
| **T1+C sequence peritumoral signature** | | | | | |
|  | | wavelet-LHH-ngtdm-Contrast | | | 0.223 |
|  | | wavelet-HLH-gldm-GrayLevelVariance | | | 0.225 |
|  | | wavelet-HLH-gldm-GrayLevelNonUniformity | | | 0.666 |
|  | | wavelet-HLH-glszm-LargeAreaHighGrayLevelEmphasis | | | 0.166 |
|  | | wavelet-HHH-gldm-GrayLevelNonUniformity | | | -0.382 |
|  | | wavelet-HLH-glszm-ZoneVariance | | | -0.062 |
| **T2WI sequence peritumoral signature** | | | | | |
|  | | wavelet-HLH-glcm-MCC | | | -0.349 |
|  | | wavelet-HLL-glszm-LargeAreaHighGrayLevelEmphasis | | | -0.103 |
|  | | original-glszm-LargeAreaHighGrayLevelEmphasis | | | -0.375 |
|  | | original-gldm-GrayLevelNonUniformity | | | -0.271 |
|  | | wavelet-HHL-glszm-LargeAreaHighGrayLevelEmphasis | | | 0.351 |
|  | | wavelet-HLH-glszm-ZoneVariance | | | -0.378 |
|  | | wavelet-LHH-glszm-LargeAreaEmphasis | | | 0.385 |
|  | | wavelet-HLH-glszm-SmallAreaEmphasis | | | 0.469 |
|  | | wavelet-HHH-glszm-HighGrayLevelZoneEmphasis | | | 0.213 |
|  | | wavelet-HHL-glszm-LargeAreaEmphasis | | | 0.108 |
|  | | wavelet-LHH-gldm-GrayLevelNonUniformity | | | -0.487 |
|  | | wavelet-HLL-gldm-GrayLevelNonUniformity | | | 0.316 |
|  | | wavelet-LHL-glszm-LargeAreaHighGrayLevelEmphasis | | | 0.049 |
|  | | original-shape-Sphericity | | | -68.423 |
|  | | wavelet-LLH-glcm-MCC | | | -0.131 |
| **DWI-ADC sequence peritumoral signature** | | | | | |
|  | | wavelet-HLH-glszm-ZoneVariance | | | 734.960 |
|  | | wavelet-HLH-glrlm-RunLengthNonUniformity | | | 3.865 |
|  | | wavelet-LHH-glszm-ZoneVariance | | | -139.866 |
|  | | wavelet-LHL-firstorder-Energy | | | -2.998 |
|  | | wavelet-HLH-gldm-DependenceNonUniformity | | | -3.686 |
|  | | wavelet-LLL-glszm-SizeZoneNonUniformity | | | 1.240 |
|  | | wavelet-HHL-firstorder-Energy | | | 1.608 |
| **Signature** | | **Feature Name** | | | **Coefficient** |
|  | | original-shape-Maximum2DDiameterColumn | | | 0.418 |
|  | | wavelet-LHH-glszm-LargeAreaEmphasis | | | 137.469 |
|  | | wavelet-HLH-glszm-LargeAreaEmphasis | | -736.561 | |
|  | | wavelet-LLL-glszm-LargeAreaLowGrayLevelEmphasis | | 24.704 | |
|  | | wavelet-LLH-firstorder-TotalEnergy | | -0.176 | |
|  | | wavelet-LLH-glszm-LargeAreaEmphasis | | -7.884 | |
|  | | wavelet-LHL-glrlm-RunLengthNonUniformity | | 11.174 | |
|  | | wavelet-HHL-glszm-LargeAreaHighGrayLevelEmphasis | | 1.687 | |
|  | | wavelet-HHL-glrlm-RunLengthNonUniformity | | -1.336 | |
|  | | wavelet-LLH-glrlm-RunLengthNonUniformity | | -4.502 | |
|  | | wavelet-HHH-glrlm-RunLengthNonUniformity | | 1.017 | |
|  | | wavelet-HHL-firstorder-Kurtosis | | 0.144 | |
|  | | original-gldm-DependenceNonUniformity | | 4.641 | |
|  | | wavelet-LHL-gldm-DependenceNonUniformity | | -1.110 | |
|  | | wavelet-HHH-glrlm-GrayLevelNonUniformity | | -9.668 | |
| **Intratumoral radiomic signature** | | | | | |
|  | | T1+C sequence signature | | 0.579 | |
|  | | T2WI sequence signature | | 0.654 | |
|  | | DWI-ADC sequence signature | | 0.494 | |
| **Peritumoral radiomic signature** | | | | | |
|  | | T1+C sequence signature | | -0.447 | |
|  | | T2WI sequence signature | | 0.706 | |
|  | | DWI-ADC sequence signature | | 0.973 | |
| **Intratumoral-peritumoral radiomic signature** | | | | | |
|  | | Intratumoral radiomic signature | | 0.402 | |
|  | | Peritumoral radiomic signature | | 0.824 | |
| **Radiomic-clinical signature** | | | | | |
|  | | Intratumoral-peritumoral radiomic signature | | 1.004 | |
|  | | Number of tumor | | -0.249 | |
|  | | Histological grade | | -0.077 | |
|  | | pTNM | | 1.081 | |
|  | | Ki67 expression | | 1.011 | |
| Abbreviation: T1+C, contrast-enhanced T1-weighted imaging; T2WI, T2-weighted imaging; DWI-ADC, diffusion-weighted imaging quantitatively measured apparent diffusion coefficients; Ki67, proliferation marker protein Ki-67; pTNM, pathological tumor–node–metastasis stage. | | | | |

**Supplementary 1** **Magnetic resonance imaging acquisition.**

In Sun Yat-sen Memorial Hospital of Sun Yat-sen University, patients underwent MRI scan using 1.5T or 3.0T scanners with 8-channel phased-array breast coils. At the scanning, an axial fat-suppressed T2-weighted imaging (T2WI) sequence and axial diffusion-weighted imaging quantitatively measured apparent diffusion coefficient (DWI-ADC) images were obtained using two b values (0 and 800 s/mm2) were acquired before contrast medium administration. An initial fat-saturated T1WI pre-contrast scan was collected before contrast-enhanced T1-weighted imaging (T1+C) images scanning, and then T1+C images were acquired as 50~70 post contrast scans at intervals of 6~8 seconds following the intravenous injection of gadolinium contrast agent. A gadolinium-based agent (Magnevist; Bayer Healthcare, Berlin, Germany) was injected using an MR imaging compatible power injector at a rate of 3.5 ml/s and at a dose of 0.2 ml/kg of body weight, followed by 20 ml saline flush with high-pressure injector.

In Sun Yat-sen University Cancer Center, patients underwent MRI scan using 1.5T or 3.0T scanners with double-breast coils. At the scanning, an axial fat-suppressed T2WI sequence and axial DWI images were obtained using two b values (0 and 800 s/mm2) were acquired before contrast medium administration. An initial fat-saturated T1WI pre-contrast scan was collected before T1+C images scanning, and then T1+C images were acquired as eight post contrast scans at intervals of 60 seconds following the intravenous injection of gadolinium contrast agent. A gadolinium-based agent (Magnevist; Bayer Healthcare, Berlin, Germany) was injected using an MR imaging compatible power injector at a rate of 3 ml/s and at a dose of 0.2 ml/kg of body weight, followed by 20 ml saline flush with high-pressure injector.

In Shunde Hospital of Southern Medical University, patients underwent MRI scan using 1.5T or 3.0T scanners with double-breast coils. At the scanning, an axial fat-suppressed T2WI sequence and axial DWI images were obtained using two b values (0 and 1,000 s/mm2) were acquired before contrast medium administration. An initial fat-saturated T1WI pre-contrast scan was collected before T1+C images scanning, and then T1+C images were acquired as six postcontrast scans at intervals of 60 seconds following the intravenous injection of gadolinium contrast agent. A gadolinium-basedagent (Gadovist; Bayer Healthcare, Berlin, Germany) was injected using an MR imaging compatible power injector at a rate of 2 ml/s and at a dose of 0.2 ml/kg of body weight, followed by a 20-mlsaline flush with high-pressure injector.

In Tungwah Hospital of Sun Yat-sen University, patients underwent MRI scan using 1.5T or 3.0T scanners with double-breast coils. At the scanning, an axial fat-suppressed T2WI sequence and axial DWI images were obtained using two b values (0 and 800 s/mm2) were acquired before contrast medium administration. An initial fat-saturated T1WI pre-contrast scan was collected before T1+C images scanning, and then T1+C images were acquired as six post contrast scans at intervals of 60 seconds following the intravenous injection of gadolinium contrast agent. A gadolinium-based agent (Magnevist; Bayer Healthcare, Berlin, Germany) was injected using an MR imaging compatible power injector at a rate of 2 ml/s and at a dose of 0.2 ml/kg of body weight, followed by 20 ml saline flush with high-pressure injector.

**Supplementary 2 Radiomic feature extraction.**

For all cohorts, multiparametric MR images from all centers were retrieved from Picture Archiving and Communication System, and radiomic features corresponding to the quantitative data obtained after computational translation of images were extracted from MR T1+C, T2WI, and DWI-ADC imaging. All of the MRIs were normalized to obtain a standard normal distribution of image intensities using the N4ITK Bias Correction code. 3D regions of interest of the breast intratumoral area (ROI-1), and peritumoral area (ROI-2 including the tumor parenchymal constituting 10-mm extension outward) were semi-automatically segmented by 3D Slicer software method (<https://www.slicer.org/>, version 4.10.2). After the ROI-1, and ROI-2 were reconstructed and segmented, the volumes of interest (VOI-1 and VOI-2) images (DICOM format) was transferred to the SlicerRadiomics code, the in-house texture extraction platform developed based on the python package “PyRadiomics”. A total of 5,718 quantitative radiomic features, including six groups of radiomic features were separately extracted from VOI-1 and VOI-2. These included shape, first-order, the gray-level co-occurrence matrix (GLCM), the gray-level size zone matrix (GLSZM), the gray-level dependence matrix (GLDM), and the neigbouring gray tone difference matrix (NGTDM). All patients were separately reassessed by three radiation oncologists (XH Li, R Zhang and QG Hu ) blinded to the patients’ clinical outcomes, MRI reassessed under the guidance of two senior radiation oncologists (Z Wu and CM Xie) who major in MRI interpretation more than 15 years.

The normalization was performed on radiomic features using a z-score transformation before significant features selection. The Random forest algorithm were applied to select the keyradiomic features which relative importance > 0.2 from T1+C, T2WI, and DWI-ADC sequence of VOI-1, and VOI-2, respectively, in the training cohort. The combination of the key features in each sequence were used to constructed T1+C, T2WI, and DWI-ADC single sequence signature. These key features were presented in the radiomic score calculation formula (Supplementary Table 6).