Supplementary Table 1. Analysis of quantitative background parenchymal enhancement metrics at various thresholds for predicting pathological complete response

Predictor	pCR(-)	pCR(+)	OR (95% CI)	*P* value	AUC (95% CI)	Sens	Spec	F1
Pre-treatment BPE percent (> 10% increase in SER) bilateral (%)	75.41 ± 11.22	75.27 ± 11.34	1.03 (0.69-1.58)	0.8678	0.49 [0.39, 0.59]	0.93 [0.12, 0.98]	0.16 [0.11, 0.97]	0.59 [0.20, 0.66]
Pre-treatment BPE percent (> 10% increase in SI) bilateral (%)	52.91 ± 18.13	52.04 ± 18.36	0.93 (0.61-1.37)	0.7360	0.52 [0.42, 0.62]	0.56 [0.08, 0.98]	0.52 [0.08, 0.98]	0.49 [0.15, 0.63]
Pre-treatment BPE percent (> 20% increase in SER) bilateral (%)	67.28 ± 12.67	64.94 ± 14.50	0.84 (0.55-1.26)	0.3665	0.54 [0.44, 0.65]	0.42 [0.20, 0.96]	0.75 [0.18, 0.94]	0.47 [0.30, 0.62]
Pre-treatment BPE percent (> 20% increase in SI) bilateral (%)	34.45 ± 17.88	32.58 ± 19.17	0.83 (0.54-1.22)	0.3364	0.55 [0.44, 0.65]	0.51 [0.23, 0.96]	0.66 [0.15, 0.92]	0.50 [0.33, 0.63]
Pre-treatment BPE percent (> 30% increase in SER) bilateral (%)	56.98 ± 13.06	52.88 ± 16.29	0.72 (0.47-1.09)	0.1055	0.58 [0.48, 0.68]	0.47 [0.24, 0.70]	0.75 [0.57, 0.93]	0.51 [0.35, 0.64]
Pre-treatment BPE percent (> 30% increase in SI) bilateral (%)	23.59 ± 15.18	22.08 ± 17.55	0.82 (0.54-1.21)	0.3079	0.55 [0.45, 0.65]	0.42 [0.17, 0.96]	0.74 [0.16, 0.95]	0.47 [0.27, 0.63]
Post-treatment BPE percent (> 10% increase in SER) bilateral (%)	70.00 ± 9.13	69.28 ± 11.25	0.93 (0.61-1.41)	0.7298	0.52 [0.41, 0.61]	0.30 [0.10, 0.72]	0.84 [0.44, 0.99]	0.39 [0.17, 0.58]
Post-treatment BPE percent (> 10% increase in SI) bilateral (%)	38.87 ± 16.52	37.69 ± 17.59	0.89 (0.58-1.34)	0.5686	0.53 [0.43, 0.62]	0.42 [0.11, 0.92]	0.74 [0.19, 0.97]	0.47 [0.20, 0.62]
Post-treatment BPE percent (>20% increase in SER) bilateral (%)	62.49 ± 9.69	61.37 ± 12.08	0.89 (0.58-1.33)	0.5434	0.53 [0.42, 0.62]	0.39 [0.08, 0.84]	0.73 [0.31, 1.00]	0.43 [0.14, 0.61]
Post-treatment BPE Percent (> 20% increase in SI) bilateral (%)	20.93 ± 14.78	20.05 ± 16.18	0.88 (0.57-1.33)	0.5055	0.53 [0.43, 0.63]	0.40 [0.10, 0.85]	0.73 [0.26, 0.98]	0.45 [0.18, 0.62]
Post-treatment BPE percent (> 30% increase in SER) bilateral (%)	53.98 ± 10.10	52.62 ± 12.82	0.84 (0.54-1.24)	0.3731	0.54 [0.45, 0.64]	0.56 [0.13, 0.75]	0.61 [0.45, 0.96]	0.52 [0.22, 0.64]
Post-treatment BPE percent (> 30% increase in SI) bilateral (%)	12.81 ± 12.28	12.41 ± 14.04	0.86 (0.55-1.31)	0.4389	0.54 [0.43, 0.63]	0.46 [0.11, 0.88]	0.67 [0.24, 0.97]	0.47 [0.19, 0.62]
Post-pretreatment change in BPE percent (> 10% increase in SER) bilateral (%)	-5.41 ± 12.68	-6.00 ± 10.66	0.95 (0.64-1.39)	0.7772	0.51 [0.41, 0.61]	0.54 [0.17, 1.00]	0.54 [0.05, 0.91]	0.49 [0.24, 0.65]
Post-pretreatment change in bpe Percent (> 10% increase in SI) bilateral (%)	-14.03 ± 19.96	-14.34 ± 17.14	0.95 (0.66-1.42)	0.8093	0.51 [0.41, 0.60]	0.81 [0.22, 1.00]	0.27 [0.04, 0.87]	0.56 [0.30, 0.65]
Post-pretreatment change in BPE percent (> 20% increase in SER) bilateral (%)	-4.79 ± 14.15	-3.57 ± 13.64	1.08 (0.74-1.63)	0.6987	0.52 [0.42, 0.62]	0.35 [0.11, 1.00]	0.75 [0.08, 0.99]	0.41 [0.19, 0.64]
Post-pretreatment change in BPE percent (> 20% increase in SI) bilateral (%)	-13.52 ± 19.70	-12.54 ± 19.18	1.07 (0.72-1.62)	0.7486	0.52 [0.43, 0.62]	0.25 [0.11, 1.00]	0.84 [0.07, 0.98]	0.33 [0.19, 0.64]
Post-pretreatment change in BPE percent (> 30% increase in SER) bilateral (%)	-3.00 ± 14.96	-0.26 ± 16.89	1.22 (0.84-1.87)	0.3240	0.55 [0.45, 0.65]	0.44 [0.17, 0.84]	0.74 [0.34, 0.95]	0.48 [0.26, 0.62]
Post-pretreatment change in BPE percent (> 30% increase in SI) Bilateral (%)	-10.79 ± 17.05	-9.67 ± 17.53	1.13 (0.76-1.72)	0.5352	0.53 [0.43, 0.63]	0.35 [0.09, 0.94]	0.75 [0.16, 0.99]	0.41 [0.16, 0.63]
Pre-treatment non-tumor side BPE percent (> 10% increase in SER) (%)	46.55 ± 19.08	49.16 ± 20.26	1.17 (0.78-1.76)	0.4243	0.54 [0.44, 0.64]	0.44 [0.10, 0.91]	0.71 [0.22, 0.98]	0.47 [0.17, 0.63]
Pre-treatment non-tumor side BPE percent (> 10% increase in SI) (%)	73.70 ± 11.93	74.80 ± 12.49	1.18 (0.78-1.78)	0.4029	0.54 [0.44, 0.64]	0.35 [0.15, 0.90]	0.76 [0.24, 0.94]	0.41 [0.23, 0.63]
Pre-treatment non-tumor side BPE percent (> 20% increase in SER) (%)	27.21 ± 17.87	29.46 ± 20.34	1.12 (0.74-1.67)	0.5828	0.53 [0.42, 0.63]	0.53 [0.09, 0.98]	0.61 [0.11, 0.99]	0.50 [0.16, 0.62]
Pre-treatment non-tumor side BPE percent (> 20% increase in SI) (%)	65.27 ± 13.54	64.36 ± 15.81	0.95 (0.62-1.43)	0.8060	0.51 [0.41, 0.62]	0.35 [0.08, 0.95]	0.78 [0.12, 0.98]	0.42 [0.15, 0.60]
Pre-treatment non-tumor Side BPE percent (> 30% increase in SER) (%)	17.01 ± 14.53	19.08 ± 18.26	1.08 (0.72-1.59)	0.7080	0.52 [0.42, 0.62]	0.49 [0.06, 0.98]	0.61 [0.09, 1.00]	0.47 [0.12, 0.62]
Pre-treatment non-tumor side BPE percent (> 30% increase in SI) (%)	55.00 ± 13.97	52.08 ± 17.66	0.83 (0.54-1.23)	0.3448	0.55 [0.44, 0.65]	0.32 [0.15, 0.72]	0.86 [0.47, 0.97]	0.41 [0.25, 0.60]
Post-treatment non-tumor side BPE percent (> 10% increase in SER) (%)	35.47 ± 16.15	36.40 ± 17.24	1.06 (0.70-1.57)	0.7597	0.52 [0.42, 0.61]	0.30 [0.13, 0.98]	0.81 [0.12, 0.97]	0.38 [0.21, 0.62]
Post-treatment non-tumor side BPE percent (> 10% increase in SI) (%)	68.44 ± 9.31	69.26 ± 11.47	1.07 (0.71-1.61)	0.7329	0.52 [0.41, 0.62]	0.26 [0.09, 0.71]	0.86 [0.42, 0.99]	0.36 [0.16, 0.59]
Post-treatment non-tumor side BPE percent (> 20% increase in SER) (%)	17.89 ± 13.72	18.64 ± 15.82	0.99 (0.65-1.49)	0.9768	0.50 [0.40, 0.60]	0.39 [0.06, 0.97]	0.69 [0.10, 0.99]	0.42 [0.11, 0.61]
Post-treatment non-tumor side BPE percent (> 20% increase in SI) (%)	60.87 ± 9.89	61.47 ± 12.30	1.02 (0.68-1.50)	0.9403	0.50 [0.40, 0.61]	0.11 [0.06, 0.93]	0.99 [0.19, 1.00]	0.19 [0.11, 0.61]
Post-treatment non-tumor side BPE percent (> 30% increase in SER) (%)	10.35 ± 11.11	11.31 ± 14.13	0.96 (0.62-1.44)	0.8352	0.49 [0.39, 0.58]	0.14 [0.08, 0.98]	0.95 [0.07, 0.99]	0.23 [0.15, 0.61]
Post-treatment non-tumor side BPE percent (> 30% increase in SI) (%)	52.58 ± 10.51	52.90 ± 13.12	1.01 (0.69-1.54)	0.9618	0.50 [0.41, 0.60]	0.35 [0.08, 0.93]	0.78 [0.19, 0.99]	0.42 [0.14, 0.63]
Post-pretreatment change in non-tumor side BPE percent (> 10% Increase in SER) (%)	-11.07 ± 21.33	-12.76 ± 18.98	0.87 (0.59-1.30)	0.4989	0.53 [0.43, 0.63]	0.89 [0.21, 1.00]	0.22 [0.09, 0.92]	0.59 [0.31, 0.66]
Post-pretreatment change in non-tumor side BPE percent (> 10% Increase in SI) (%)	-5.25 ± 13.97	-5.54 ± 12.28	1.00 (0.69-1.49)	0.9851	0.50 [0.40, 0.59]	0.35 [0.08, 1.00]	0.72 [0.05, 0.99]	0.40 [0.14, 0.64]
Post-pretreatment change in non-tumor side BPE percent (> 20% Increase in SER) (%)	-9.36 ± 19.89	-10.82 ± 20.46	0.91 (0.61-1.38)	0.6441	0.52 [0.42, 0.62]	0.33 [0.18, 0.97]	0.76 [0.11, 0.94]	0.40 [0.27, 0.64]
Post-pretreatment change in non-tumor side BPE percent (> 20% Increase in SI) (%)	-4.44 ± 15.56	-2.89 ± 15.10	1.13 (0.76-1.69)	0.5270	0.53 [0.43, 0.63]	0.35 [0.14, 0.94]	0.76 [0.18, 0.97]	0.41 [0.22, 0.63]
Post-pretreatment change in non-tumor side BPE percent (> 30% Increase in SER) (%)	-6.71 ± 16.65	-7.77 ± 18.34	0.95 (0.63-1.43)	0.7868	0.51 [0.41, 0.61]	0.81 [0.06, 0.92]	0.28 [0.22, 1.00]	0.56 [0.11, 0.65]
Post-pretreatment change in non-tumor side BPE percent (> 30% increase in SI) (%)	-2.50 ± 16.23	0.82 ± 17.89	1.27 (0.85-1.91)	0.2364	0.56 [0.45, 0.67]	0.58 [0.19, 0.73]	0.61 [0.49, 0.96]	0.54 [0.29, 0.64]

AUC, area under the curve; OR, odds ratio; CI, confidence interval; pCR, pathological complete response; BPE, background parenchymal enhancement; SER, signal enhancement ratio; SI, signal intensity.

Supplementary Table 2. Comparison of background parenchymal enhancement metrics between triple-negative and non-triple-negative breast cancer subtypes

BPE	*P*	Non-triple negative (median)	Triple negative (median)
Pre-treatment BPE percent (> 10% increase in SI) bilateral (%)	0,769891	51,54372	52,57403
Pre-treatment BPE percent (> 10% increase in SER) bilateral (%)	0,257835	75,72531	78,87972
Pre-treatment BPE percent (> 20% increase in SI) bilateral (%)	0,847159	31,72326	27,84688
Pre-treatment BPE percent (> 20% increase in SER) bilateral (%)	0,235644	67,67556	69,82334
Pre-treatment BPE percent (> 30% increase in SI) bilateral (%)	0,645288	19,49836	16,87578
Pre-treatment BPE percent (> 30% increase in SER) bilateral (%)	0,358425	56,02076	56,06947
Post-treatment BPE percent (> 10% increase in SI) bilateral (%)	0,420825	36,14276	39,87552
Post-treatment BPE percent (> 10% increase in SER) bilateral (%)	0,165902	69,38188	70,42771
Post-treatment BPE percent (> 20% increase in SI) bilateral (%)	0,684818	15,97026	18,50129
Post-treatment BPE percent (> 20% increase in SER) bilateral (%)	0,486337	62,18983	62,41562
Post-treatment BPE percent (> 30% increase in SI) bilateral (%)	0,889986	8,322559	9,443901
Post-treatment BPE percent (> 30% increase in SER) bilateral (%)	0,94035	53,99041	53,32279
Post-pretreatment change in BPE percent (> 10% increase in SI) bilateral (%)	0,958406	-14,038	-14,5079
Post-pretreatment change in BPE percent (> 10% increase in SER) bilateral (%)	0,92953	-6,01129	-4,24333
Post-pretreatment change in BPE percent (> 20% increase in SI) bilateral (%)	0,825906	-11,9928	-11,5299
Post-pretreatment change in BPE percent (> 20% increase in SER) Bilateral (%)	0,609908	-3,75501	-6,20102
Post-pretreatment change in BPE percent (> 30% increase in SI) bilateral (%)	0,651811	-8,70291	-8,78555
Post-pretreatment change in BPE percent (> 30% increase in SER) bilateral (%)	0,39766	-2,12864	-1,75778
Pre-treatment non-tumor side BPE percent (> 10% increase in SI) (%)	0,41561	75,03126	77,00648
Pre-treatment non-tumor side BPE percent (> 20% increase in SI) (%)	0,360804	67,66644	66,69952
Pre-treatment non-tumor side BPE percent (> 30% increase in SI) (%)	0,500648	56,18949	55,66352
Pre-treatment non-tumor side BPE percent (> 10% increase in SER) (%)	0,847159	47,16325	45,48035
Pre-treatment non-tumor side BPE percent (> 20% increase in SER) (%)	0,861391	25,62391	23,56294
Pre-treatment non-tumor side BPE percent (> 30% increase in SER) (%)	0,678166	13,37621	12,59318
Post-treatment non-tumor side BPE percent (> 10% increase in SI) (%)	0,242586	69,13845	68,02481
Post-treatment non-tumor side BPE percent (> 20% increase in SI) (%)	0,547557	61,83777	59,97931
Post-treatment non-tumor side BPE percent (> 30% increase in SI) (%)	0,799624	53,60787	51,78099
Post-treatment non-tumor side BPE percent (> 10% increase in SER) (%)	0,240747	33,87504	37,39512
Post-treatment non-tumor side BPE percent (> 20% increase in SER) (%)	0,376164	13,967	16,0479
Post-treatment non-tumor side BPE percent (> 30% increase in SER) (%)	0,391144	6,514968	7,840605
Post-pretreatment change in non-tumor side BPE percent (> 10% Increase in SI) (%)	0,796093	-5,52848	-4,01582
Post-pretreatment change in non-tumor side BPE percent (> 20% Increase in SI) (%)	0,7785	-3,51038	-4,30912
Post-pretreatment change in non-tumor side BPE percent (> 30% Increase in SI) (%)	0,639219	-2,21777	-1,44893
Post-pretreatment change in non-tumor side BPE percent (> 10% increase in SER) (%)	0,578423	-11,9915	-9,78816
Post-pretreatment change in non-tumor side BPE percent (> 20% increase in SER) (%)	0,678941	-7,92271	-8,15162
Post-pretreatment change in non-tumor side BPE percent (> 30% increase in SER) (%)	0,740203	-5,1115	-5,144

Supplementary Table 3. Pre-specified subgroup analyses of BPE (> 30% SER bilateral) vs. pCR. Mann–Whitney U tests

Subgroup	n (pCR/total)	Pre-BPE pCR– (median)	Pre-BPE pCR+ (median)	*P*	Post-BPE pCR– (median)	Post-BPE pCR+ (median)	*P*	ΔBPE pCR– (median)	ΔBPE pCR+ (median)	*P*
HER2 positive	32/61	53.6	56.7	0.812	53.6	53.3	0.691	-1.2	-3.6	0.891
HER2 negative	25/81	59.3	49.8	0.014	54.7	50.4	0.083	-2.8	+2.0	0.304
HR positive	26/74	58.3	44.6	0.003	54.3	53.1	0.959	-3.5	+6.8	0.017
HR negative	31/68	56.8	60.3	0.684	55.8	49.5	0.180	-1.2	-4.9	0.423
Luminal A/B	8/41	59.4	44.9	0.004	54.5	54.0	0.961	-2.9	+12.0	0.029
HER2+ subtype	32/61	55.3	56.7	0.960	53.1	53.3	0.448	-5.1	-3.6	0.608
TNBC	17/40	56.8	53.9	0.262	57.9	47.7	0.010	-0.9	-6.0	0.682
Premenopausal	30/69	57.8	51.3	0.129	54.3	50.2	0.541	-2.9	-5.4	0.449
Postmenopausal	27/73	57.7	53.4	0.395	55.1	52.7	0.780	-2.6	+2.0	0.346

Bold p-values indicate $P < 0.05$. Subgroup analyses are exploratory and reported without multiplicity correction. BPE, background parenchymal enhancement; HER2, human epidermal growth factor receptor 2; HR, hormone receptor; pCR, pathological complete response; SER, signal enhancement ratio; TNBC, triple-negative breast cancer.

Supplementary Table 4. Incremental value of the multivariable model relative to a simple HER2 + Ki-67 model. Continuous covariates standardized (per 1 SD); L2 logistic regression; five-fold StratifiedKFold cross-validation (seed 42); apparent-AUC 95% CIs from 2000 bootstrap resamples

Model	Predictors (k)	Apparent AUC (95% CI)	5-fold CV AUC (mean ± SD)	Sens	Spec	F1
HER2 + Ki-67 (simple)	2	0.71 (0.62–0.79)	0.71 ± 0.08	0.81	0.56	0.66
HER2 + Ki-67 + BPE (pre/post/delta)	5	0.73 (0.64–0.81)	0.72 ± 0.10	0.81	0.59	0.67
Full clinicopathological, no BPE	8	0.73 (0.64–0.80)	0.68 ± 0.09	0.88	0.51	0.67
Full multivariable model (Table 3)	10	0.76 (0.67–0.83)	0.70 ± 0.10	0.88	0.60	0.71

Incremental-value tests vs the simple HER2 + Ki-67 model: DeLong test on apparent AUC, full vs simple ΔAUC +0.05, p = 0.12; likelihood-ratio test adding BPE to HER2 + Ki-67, $\chi^2(2) = 2.58$, p = 0.28; adding all remaining covariates to HER2 + Ki-67, $\chi^2(8) = 11.3$, p = 0.18. Sensitivity, specificity and F1 are at the Youden-derived threshold on the apparent model. AUC, area under the curve; BPE, background parenchymal enhancement; CI, confidence interval; CV, cross-validation; HER2, human epidermal growth factor receptor 2; Ki-67, marker of proliferation Ki-67; SD, standard deviation; Sens, sensitivity; Spec, specificity.