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T1-2N1M0 triple-negative breast cancer patients from the SEER database showed potential benefit from post-mastectomy radiotherapy

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Abstract. The effects of post-mastectomy radiotherapy (PMRT) on different subtypes of T1-2N1M0 breast cancer remain controversial. Patients with T1-2N1M0 breast cancer treated by mastectomy or mastectomy and PMRT were identified from the 2010-2013 dataset from the Surveillance, Epidemiology and End Results (SEER) registry. A total of 7,466 patients with the 7th American Joint Committee on Cancer stage (Tumor-Node-Metastasis stages 1-2, 1 and 0, respectively) including 2,760 cases (36.97%) treated by mastectomy and PMRT and 4,706 cases (63.03%) treated by mastectomy alone were analyzed in this study. The follow-up time for patients in the dataset used from the SEER registry was 0-59 months. The breast cancer-specific survival (BCSS) of the patients was derived from the SEER dataset and stratified by treatment approach. A propensity score matching (PSM) analysis (experimental group: Control group ratio, 1:1) was conducted. Using univariate and multivariate analyses Cox proportional hazards analyses, PMRT was identified as an independent prognostic factor for triple-negative breast cancer (TNBC). Before PSM analysis, the BCSS favored PMRT in the hormone receptor (HR)$^+$/human epidermal growth factor receptor 2 (HER2)$^+$ (P=0.025) and HR$^-$/HER2$^-$ groups (P=0.010) but not in the HR$^+$/HER2$^-$ (P=0.346) and HR$^-$/HER2$^+$ (P=0.288) groups. Following PSM analysis, BCSS favored PMRT alone in the TNBC (HR$^-$/HER2$^-$) group (P=0.025). Patients with T1-2N1M0 TNBC may benefit from radiotherapy post-mastectomy.

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Introduction

Radiotherapy is a significant adjuvant therapy for breast cancer. Post-mastectomy radiation therapy (PMRT) is always recommended for patients at high risk of recurrence, including those with ≥4 positive axial lymph nodes (ALNs) or a tumor >5 cm, independent of the nodal status and resection margins (1). Adjuvant PMRT has been shown to be extremely useful at improving the survival of high-risk patients, however the benefits and demerits of radiotherapy for breast cancer patients have not been established (2).

In 2014, the Early Breast Cancer Trialists' Collaborate Group published a study on the value of PMRT for breast cancer patients (3). The results of that systematic review and meta-analysis of 22 trials demonstrated that PMRT significantly reduced not only the local recurrence rate, but also the breast cancer mortality rate in patients with 1-3 positive ALNs (3). The 2015 European Society for Medical Oncology guidelines recommend PMRT for high-risk patients and also suggest the routine use of PMRT for patients with 1-3 positive ALNs (4). However, the primary limitation of relevant studies is that they were not randomized control studies. Whether patients with Tumor-Node-Metastasis (TNM) stage of T1-2N1M0 require PMRT remains controversial (5,6). T1-2N1M0 refers to: T1-2, maximum tumor diameter ≤50 mm; N1, micrometastasis (maximum diameter >0.2 mm, or >200 tumor cells in a single lymph node tissue section, but the maximum diameter ≤2 mm), 1-3 axillary lymph node metastasis, at least 1 metastatic lesion >2 mm and transfer (including micro transfer); M0, no distant metastasis (7).

In brief, selection of breast cancer patients for PMRT is based on established clinical pathology parameters including the size of the mass and lymph node (LN) status, factors which contribute to the baseline risk of local recurrence (8). Nevertheless, a growing body of data has demonstrated the

importance of molecular subtypes in treating patients with breast cancer and predicting their prognoses (9).

Breast cancer has been demonstrated to be a heterogeneous group of diseases (10). Perou *et al* (11) first discovered the intrinsic subtypes of breast cancer using bioinformatics analysis of gene expression profiling data. The different molecular subtypes of breast cancer have distinct outcomes, and therefore, breast cancer subtypes have been widely used clinically to select adjuvant systemic therapies and predict patient prognosis (12). Comprehensive treatment strategies for breast cancer are based on molecular subtypes, but do not take the individualization of radiotherapy into account (13). There is lack of evidence for making firm recommendations about PMRT in the various breast cancer subgroups. The precise relationship between the intrinsic sensitivity of radiotherapy and the molecular subtypes is not yet known and the mechanisms underlying the different responses of the subtypes have not been elucidated.

As the concept and techniques of genotyping continue to develop, molecular typing has become a standardized treatment for the guidance of chemotherapy and endocrine therapy for patients with breast cancer (14,15). These advances raise the question of whether molecular subtypes can be used to predict the response to PMRT and the prognosis. The present study was conducted to assess the effects of PMRT administered to patients with T1-2N1M0 breast cancer and to evaluate the treatment-predictive effect of breast cancer molecular subtypes among patients in the Surveillance, Epidemiology, and End Results (SEER) registry who underwent PMRT.

Patients and methods

Patient selection. The SEER registry of the National Cancer Institute (USA) is a comprehensive source of information about the occurrence of all new cancer cases among people residing in areas that take part in the SEER program (https://seer.cancer.gov/). Of the 181,878 patients with a pathology-based diagnosis of breast cancer between 2010 and 2013, this study restricted analysis to females with a diagnosis of a single primary and malignant breast neoplasm. The median follow-up time was 34 months (range, 0-59 months). Among these, 2,760 patients were treated with radiotherapy (36.97%; PMRT group). The other 4,706 patients (63.03%) were treated without radiotherapy and were classified as no-PMRT group. As the SEER registry began tracking information regarding HER2/neu status in 2010, this date was used as the earliest period for this study. Inclusion criteria for this study were as follows: i) Diagnosis confirmed by histology; ii) female patients with unilateral breast lesions; iii) mastectomy was performed (surgery of primary site variable values of 50-74); and iv) patients were diagnosed with breast cancer defined as T1-2N1M0 stage, according to the 7th American Joint Committee on Cancer (AJCC) cancer staging manual (7).

The following cases were excluded: i) Patients diagnosed based on an autopsy or death certificate; ii) patients whose PMRT was uncertain; iii) patients who did not undergo a mastectomy; iv) patients with an unknown molecular subtype, unknown age at diagnosis, unknown year of diagnosis, unknown laterality or unknown survival months; and v) patients who received preoperative systemic therapy (radiotherapy and/or chemotherapy). After these exclusions, a total of 7,466 patients were included in the present study for analysis.

Table I represents the demographic variables of the patients selected: Ethnicity (white, black, others); age at diagnosis (<55, ≥55 years); year of diagnosis (2010-2013); and marital status (married, unmarried but domestic partner, unmarried, separated, widowed, divorced, unknown). The cancer characteristics included the following: Laterality (left, right); AJCC T-stage (T1, T2); number of positive LNs (1, 2 or 3); histological type (code 8500/3, infiltrating duct carcinoma; code 8520/3, lobular carcinoma; code 8522/3, infiltrating duct and lobular carcinoma; others); histological grade (well differentiated, moderately differentiated, poorly differentiated, undifferentiated, unknown); hormone receptor (HR) status (positive, negative); and human epidermal growth factor receptor 2 (HER2) status (positive, negative) (Table I).

The treatment characteristics of the patients were chemotherapy (yes, no/unknown) and radiotherapy (PMRT group, no-PMRT group). The tumor molecular subtypes were classified as 4 mutually exclusive categories: $HR^+/HER2^-$, $HR^-/HER2^+$, $HR^+/HER2^+$ and $HR^-/HER2^-$ [defined as triple-negative breast cancer (TNBC)]. HR^+ was defined as estrogen receptor $(ER)^+$, progesterone receptor $(PR)^+$ or borderline positive (those that could not be defined as ER^+ or PR^+). In contrast, HR^- was defined as ER^- and PR^-. Individuals who had a borderline HER2 status were grouped in another category 'unknown HER2 status' (16).

Statistical analysis. The baseline characteristics of the patients were assessed using a Pearson's χ^2-test and the aforementioned factors were compared between the PMRT group and the no-PMRT group. The breast cancer-specific survival (BCSS) was extracted from the SEER database. Kaplan-Meier survival curves were generated and the log-rank test was used to identify significant differences between the curves. The prognostic value of PMRT was analyzed by Cox univariate and multivariate regression analyses. Due to the statistical non-significance of the diagnosis year in the univariate regression analysis, this factor was excluded from the multivariate regression analysis. The HR and HER2 statuses of the patients were excluded to avoid a repetition in the analysis. Tests of interaction were used in the Cox multivariate regression analysis. Hazard ratios and 95% confidence intervals (95% CIs) were calculated.

To adjust for potential confounding factors in patients with TNBC, individual propensity score matching (PSM) was performed, in which randomly selected individuals in the PMRT group were paired with comparable individuals in the no-PMRT group. The confounding factors were ethnicity, age, year of diagnosis, marital status, laterality, T stage, positive LN status, histological type, histological grade and chemotherapy. All data analyses were performed using SPSS version 22 (IBM Corp.). All the statistics tests performed were double-sided, and $P<0.05$ was considered to indicate a statistically significant difference.

Outcome measurement. The main endpoint of this study was 5-year BCSS. The patients were recorded as alive or dead in the SEER database, and the option of 'completed months of follow-up' contained the patients survival time in months. The BCSS was calculated from the date of diagnosis to the date of

Table I. Clinicopathological characteristics of the patients in PMRT group and no-PMRT group.

Characteristics	Cases, n (%)	PMRT, n (%)	No PMRT, n (%)	P-value
Total	7,466 (100)	2,760 (37)	4,706 (63)	
Ethnicity				0.500
White	5,699 (76)	2,095 (37)	3,604 (63)	
Black	973 (13)	376 (39)	597 (61)	
Others	794 (11)	289 (36)	505 (64)	
Age at diagnosis, years				<0.001
<55	2,626 (35)	1,231 (47)	1,395 (53)	
≥55	4,840 (65)	1,529 (32)	3,311 (68)	
Year of diagnosis				0.002
2010	2,032 (27)	685 (34)	1,347 (66)	
2011	1,931 (26)	760 (39)	1,171 (61)	
2012	1,834 (25)	699 (38)	1,135 (62)	
2013	1,669 (22)	616 (37)	1,053 (63)	
Marital status				<0.001
Married/unmarried or domestic partner	4,152 (56)	1,631(39)	2,521 (61)	
Never married	1,153 (15)	442 (38)	711 (62)	
Unmarried/separated/widowed	1,783 (24)	552 (31)	1,135 (69)	
Unknown	378 (5)	135 (36)	1,053 (64)	
Laterality				0.353
Left	3,807 (51)	1,388 (36)	2,419 (64)	
Right	3,659 (49)	1,372 (38)	2,287 (62)	
T stage				<0.001
T1	2,791 (37)	867 (31)	1,924 (69)	
T2	4,675 (63)	1,893 (40)	2,782 (60)	
Positive lymph node, n				<0.001
1	3,922 (53)	1,189 (30)	2,733 (70)	
2	2,264 (30)	922 (41)	1,342 (59)	
3	1,280 (17)	649 (51)	631 (49)	
Histological type				0.150
IDC	5,956 (80)	2,239 (38)	3,717 (62)	
ILC	564 (7)	200 (35)	364 (65)	
IDC+ILC	434 (6)	146 (34)	288 (66)	
Others	512 (7)	175 (34)	337 (66)	
Histological grade				<0.001
I	828 (11)	231 (28)	597 (72)	
II	3,198 (43)	1,111 (35)	2,087 (65)	
III	3,233 (43)	1,337 (41)	1,896 (59)	
Unknown	207 (3)	81 (39)	126 (61)	
HR status				<0.001
HR^+	6,138 (82)	2,204 (36)	3,934 (64)	
HR^-	1,328 (18)	556 (42)	772 (58)	
HER2 status				0.035
$HER2^+$	1,477 (20)	581 (39)	896 (61)	
$HER2^-$	5,989 (80)	2,179 (36)	3,810 (64)	
Subtype				<0.001
$HR^+/HER2^-$	5,102 (68)	1,781 (35)	3,321 (65)	
$HR^-/HER2^+$	441 (6)	158 (36)	283 (64)	
$HR^+/HER2^+$	1,036 (14)	423 (41)	613 (59)	
$HR^-/HER2^-$	887 (12)	398 (45)	489 (55)	

Table I. Continued.

Characteristics	Cases, n (%)	PMRT, n (%)	No PMRT, n (%)	P-value
Chemotherapy				<0.001
Yes	5,318 (71)	2,462 (46)	2,856 (54)	
No/unknown	2,148 (29)	298 (14)	1,850 (86)	

PMRT, post-mastectomy radiotherapy; IDC, invasive ductal carcinoma; ILC, invasive lobular carcinoma; HR, hormone receptor; HER2, human epidermal growth receptor-2.

death due to breast cancer or the last follow-up. Patients who were alive were censored on the date of their last visit.

Results

Clinicopathological characteristics of breast cancer patients. A total of 7,466 T1-2N1M0 breast cancer patients treated with a mastectomy were identified from the SEER database. The clinical characteristics of the patients, and the comparison between the PMRT and no-PMRT group are summarized in Table I. As presented in Table I, 65% (n=4,840) of patients were diagnosed after the age of 55 years. Of these 4,840 patients, 32% received PMRT and 68% did not. Analysis of the data also revealed that 68% (n=5,102) of the patients were $HR^+/HER2^-$, 6% (n=441) were $HR^-/HER2^+$, 14% (n=1,036) were $HR^+/HER2^+$ and 12% (n=887) were $HR^-/HER2^-$ (TNBC). Using the Pearson χ^2-test, significant differences were observed between the PMRT and the no-PMRT groups with regard to age at diagnosis (P<0.001), year of diagnosis (P=0.002), marital status (P<0.001), T stage (P<0.001), positive LN (P<0.001), histological grade (P<0.001), HR status (P<0.001), HER2 status (P=0.035), subtype (P<0.001) and chemotherapy (P<0.001) (Table I). Ethnicity (P=0.500), laterality (P=0.353) and histological type (P=0.150) were not significantly different between the PMRT and no-PMRT group (Table I).

Prognostic factors. Univariate and multivariate analyses identified the following independent prognostic factors: Ethnicity (P=0.002; P=0.031); age at diagnosis (P=0.006; P=0.028); T stage (P<0.001; P<0.001); histological grade (P<0.001; P<0.001); molecular subtype (P<0.001; P<0.001); and PMRT (P=0.025; P=0.005) (Table II). The multivariate analysis examining subtypes demonstrated that PMRT was an independent prognostic factor for TNBC (Hazard ratio, 1.519; 95% CI, 1.044-2.208; P=0.029) (Table III).

Survival analysis. Kaplan-Meier analysis revealed that, among the 4 subtypes of patients with breast cancer, TNBC was associated with the worst BCSS (P<0.001; Fig. 1). Patients with T1-2N1M0 breast cancer treated with PMRT showed improved BCSS compared with those not treated with PMRT (P=0.027; Fig. 2). The Kaplan-Meier analysis of the 4 molecular subtypes revealed that both the $HR^+/HER2^+$ (Hazard ratio, 5.208; 95% CI, 4.141-6.550; P=0.025) and $HR^-/HER2^-$ (Hazard ratio, 3.828; 95% CI, 2.940-4.983; P=0.010) patients benefited from PMRT (Fig. 3). However, no significant statistical difference was observed in the $HR^+/HER2^-$ (hazard ratio, 0.857; 95% CI, 0.621-1.182; P=0.346) and $HR^-/HER2^+$ (hazard ratio, 0.649; 95% CI, 0.292-1.442; P=0.288).

PSM analysis. To decrease the influence of potential confounding factors, a PSM analysis was conducted between the PMRT and no-PMRT group of the 4 molecular subtypes of T1-2N1M0 patients. The Kaplan-Meier analysis after PSM demonstrated that only patients with TNBC benefited from PMRT (hazard ratio, 0.6208; 95% CI, 0.4009-0.9615; P=0.025) while patients with the other 3 molecular subtypes did not (Fig. 4). The PSM analysis assigned 271 patients with T1-2N1M0 TNBC to the PMRT group, matched with 271 patients in the no-PMRT group (Fig. S1). Of the 542 patients with T1-2N1M0 TNBC, no factors differed significantly between the 2 groups (Table IV).

Discussion

According to the National Comprehensive Cancer Network (USA), after a patient with breast cancer has undergone a total mastectomy with N2/3 ALNs or a T3/4 primary tumor, PMRT is a standard adjuvant therapy (17). The application of PMRT for T1-2N1M0 breast cancer remains controversial (18-21). The St. Gallen Breast Cancer Conference pointed out that ~64% of experts did not recommend PMRT as a routine treatment for T1-2N1M0 breast cancer (22). Among these experts, 62% agreed that PMRT can be beneficial for patients with adverse prognostic factors (23). In the present study, the molecular subtype of breast cancer was a significant predictor for radiosensitivity.

Breast tumors are heterogeneous, and the heterogeneity determines the strategy for cancer follow-up treatment (24). Previous studies have investigated the relationships between histopathological patterns, including tumor size, histological type and histological grade, and therapy and prognosis (25). Molecular subtypes of cancer are based on gene expression profiling, which reflects the intrinsic nature of the tumor cells (26). Recent studies have demonstrated that these molecular subtypes are associated with different clinical characteristics and outcomes (12,24-29). Due to the high cost of gene expression tests, immunohistochemistry, which is a cheaper alternative, was proposed along with criteria set by the expert panel of the 13th St. Gallen International Breast Cancer Conference (23). However, very few studies of patients with T1-2N1M0 cancer have evaluated the role of molecular subtyping in guiding decisions regarding radiotherapy after mastectomy.

Table II. Univariate and multivariate analysis to evaluate breast cancer-specific survival according to clinicopathological variables from the SEER database.

	Univariate analysis		Multivariate analysis	
Variables	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Ethnicity		0.002		0.031
White	Reference		Reference	
Black	1.380 (1.823-1.823)	0.023	1.036 (0.778-1.379)	0.811
Others	0.556 (0.349-0.886)	0.014	0.54 (0.339-0.862)	0.010
Age at diagnosis, years				
<55	Reference		Reference	
≥55	1.385 (1.098-1.747)	0.006	1.314 (1.029-1.677)	0.028
Year of diagnosis		0.690		
2010	Reference			
2011	0.89 (0.685-1.156)	0.382		
2012	1.065 (0.786-1.444)	0.683		
2013	0.945 (0.588-1.518)	0.815		
Marital status		0.009		0.204
Married/unmarried but domestic partner	Reference		Reference	
Unmarried	1.344 (0.997-1.812)	0.053	1.217 (0.895-1.654)	0.210
Separated/widowed	1.479 (1.156-1.891)	0.002	1.254 (0.972-1.617)	0.082
Unknown	1.467 (0.932-2.310)	0.098	1.394 (0.884-2.198)	0.153
Laterality				
Left	Reference			
Right	0.815 (0.66-1.007)	0.058		
T stage				
T1	Reference		Reference	
T2	2.625 (2.011-3.427)	<0.001	2.356 (1.796-3.09)	<0.001
Positive lymph nodes, n		0.267		0.202
1	Reference		Reference	
2	0.935 (0.73-1.196)	0.590	0.916 (0.715-1.174)	0.489
3	1.199 (0.91-1.58)	0.197	1.212 (0.916-1.603)	0.179
Histological type		0.006		0.337
IDC	Reference		Reference	
ILC	0.42 (0.241-0.733)	0.002	0.604 (0.34-1.073)	0.085
IDC+ILC	0.603 (0.353-1.03)	0.064	0.933 (0.54-1.610)	0.802
Others	0.899 (0.593-1.362)	0.615	0.848 (0.557-1.292)	0.444
Histological grade		<0.001		<0.001
I	Reference		Reference	
II	1.420 (0.845-2.384)	0.185	1.264 (0.749-2.133)	0.380
III	3.809 (2.328-6.232)	<0.001	2.213 (1.307-3.747)	0.003
Unknown	1.762 (0.731-4.249)	0.207	1.275 (0.521-3.119)	0.595
HR status				
HR^+	Reference			
HR^-	4.176 (3.382-5.156)	<0.001		
HER2 status				
$HER2^+$	Reference			
$HER2^-$	1.361 (1.016-1.823)	0.039		
Subtype		<0.001		<0.001
$HR^+/HER2^-$	Reference		Reference	
$HR^-/HER2^+$	1.911 (1.263-2.892)	0.002	1.464 (0.951-2.254)	0.083
$HR^+/HER2^+$	0.842 (0.56-1.266)	0.410	0.711 (0.469-1.08)	0.110
$HR^-/HER2^-$	5.208 (4.141-6.550)	<0.001	3.828 (2.94-4.983)	<0.001

Table II. Continued.

Variables	Univariate analysis		Multivariate analysis	
	Hazard Ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Chemotherapy				
Yes	Reference		Reference	
No/unknown	1.23 (0.982-1.542)	0.071	1.518 (1.182-1.949)	0.001
PMRT				
Yes	Reference		Reference	
No	1.294 (1.033-1.622)	0.025	1.413 (1.112-1.796)	0.005

IDC, invasive ductal carcinoma; ILC, invasive lobular carcinoma; HR, hormone receptor; HER2, human epidermal growth receptor-2; PMRT, post-mastectomy radiotherapy.

Table III. Multivariate analysis to evaluate breast cancer-specific survival by molecular subtype.

Subtypes	Hazard ratio (95% CI)	P-value
$HR^+/HER2^-$, PMRT vs. no PMRT	1.189 (0.836-1.692)	0.335
$HR^-/HER2^{+-}$, PMRT vs. no PMRT	1.108 (0.429-2.857)	0.833
$HR^+/HER2^{+-}$, PMRT vs. no PMRT	2.391 (0.845-6.763)	0.100
$HR^-/HER2^-$, PMRT vs. no PMRT	1.519 (1.044-2.208)	0.029

PMRT, post-mastectomy radiotherapy; HR, hormone receptor; HER2, human epidermal growth receptor-2.

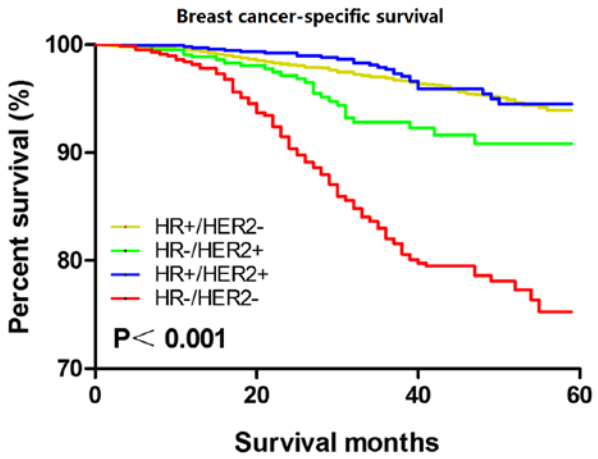

Figure 1. Kaplan-Meier curve of breast-cancer specific survival for patients with 4 molecular subtypes of cancer. HR, hormone receptor; HER2, human epidermal growth factor receptor 2.

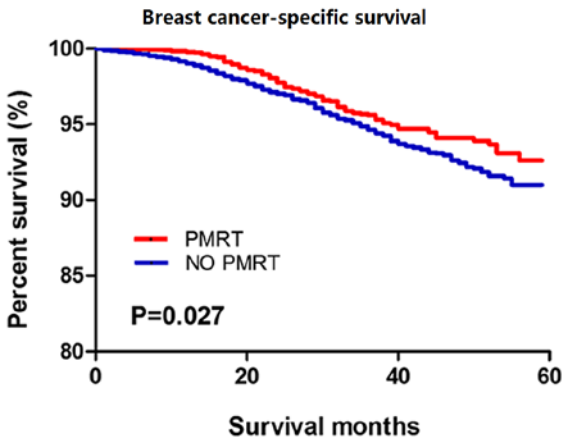

Figure 2. Kaplan-Meier curves of breast-cancer specific survival for patients who received PMRT or did not. PMRT, post-mastectomy radiotherapy.

In the Swedish Breast Cancer Group 91 Radiotherapy trial, radiotherapy showed a trend to improve the BCSS for patients with TNBC; however, this trend did not reach significance (30). The results of the present study demonstrated that PMRT can improve the BCSS of patients with T1-2N1M0 TNBC. Of patients with BRCA-1 mutant breast cancer, 60-80% are TNBC, which implies a high association between these types of breast cancer (31). When the BRCA-1 gene is mutated, damaged DNA cannot be repaired by homologous recombination, which is the main method for the repair of double-stranded DNA breaks (31). The dysfunction or deficiency of BRCA-1 may increase the susceptibility to radiotherapy (31).

The main strength of a SEER analysis is that the SEER database has access to a much larger cohort of patients compared with that of a single institution. In the present study, PSM was also conducted to reduce the effects of confounding factors. However, this study had several limitations. Firstly, the SEER registry does not provide any information on the details of treatments such as

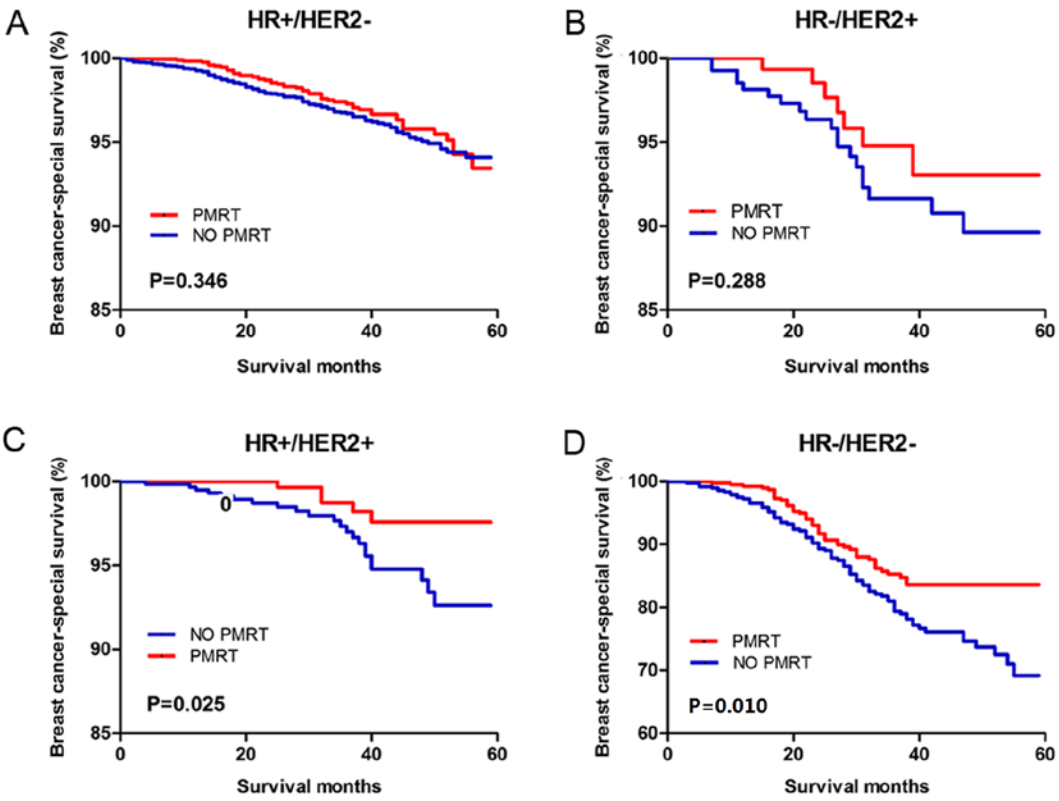

Figure 3. Kaplan-Meier curves of breast-cancer specific survival for patients with the different molecular subtypes of breast cancer who received PMRT before propensity score matching. (A) $HR^+/HER2^-$; (B) $HR^-/HER2^+$; (C) $HR^+/HER2^+$; and (D) $HR^-/HER2^-$. PMRT, post-mastectomy radiotherapy; HR, hormone receptor; HER2, human epidermal growth factor receptor 2.

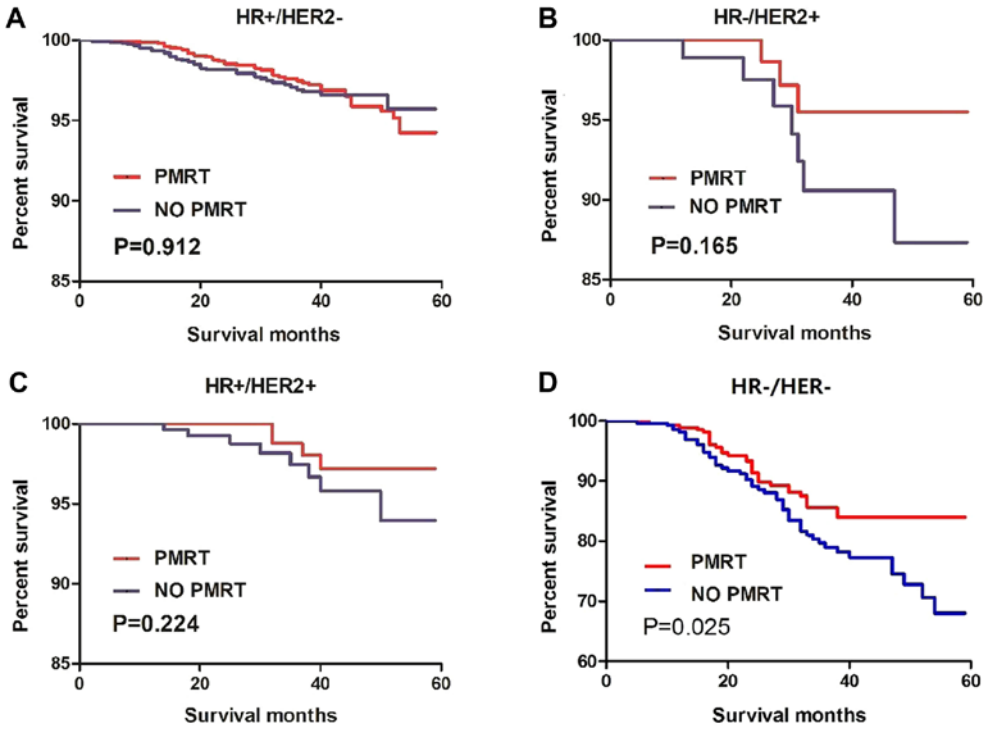

Figure 4. Kaplan-Meier curve of breast cancer-specific survival for patients with the different molecular subtypes of breast cancer who received PMRT after propensity score matching. (A) $HR^+/HER2^-$; (B) $HR^-/HER2^+$; (C) $HR^+/HER2^+$; and (D) $HR^-/HER2^-$. PMRT, post-mastectomy radiotherapy; HR, hormone receptor; HER2, human epidermal growth factor receptor 2.

chemotherapy regimens, HER2-targeted therapy, endocrine therapy or methods of PMRT. In addition, the SEER registry lacks information on the specific positive rates of ER/PR and Ki-67, and therefore, the 4 molecular types examined

Table IV. Clinicopathological characteristic before and after PSM in patients with triple-negative breast cancer with and without PMRT.

	Before PSM				After PSM			
Characteristics	PMRT, n	No PMRT, n	χ^2	P-value	PMRT, n	No PMRT, n	χ^2	P-value
Ethnicity			0.537	0.764			0.162	0.922
White	286	350			192	191		
Black	75	99			51	54		
Others	37	40			28	26		
Age at diagnosis, years			8.551	0.003			3.411	0.065
<55	175	168			117	96		
≥55	223	321			154	175		
Year of diagnosis			3.37	0.338			0.785	0.853
2010	97	142			66	73		
2011	110	129			81	75		
2012	108	113			65	61		
2013	83	105			59	62		
Marital status			2.93	0.403			2.583	0.461
Married/unmarried or domestic partner	228	252			164	146		
Never married	59	83			37	46		
Unmarried/separated/widowed	91	126			57	65		
Unknown	20	28			13	14		
Laterality			1.563	0.211			0.119	0.731
Left	217	246			146	142		
Right	181	243			125	129		
T stage			6.643	0.010			0	1.000
T1	95	155			63	63		
T2	303	334			208	208		
Positive lymph nodes, n			7.984	0.018			1.598	0.450
1	201	285			166	152		
2	114	134			72	84		
3	83	70			33	35		
Histologic type			0.581	0.446			0	1.000
IDC	358	432			246	246		
ILC/IDC+ILC/others	40	57			25	25		
Histological grade			11.514	0.003			1.811	0.404
I/II	34	79			24	33		
III	352	395			239	232		
Unknown	12	15			8	6		
Chemotherapy			72.69	<0.001			0.31	0.861
Yes	379	361			253	254		
No/Unknown	19	128			18	17		

PSM, propensity score matching; PMRT, post-mastectomy radiotherapy; IDC, invasive ductal carcinoma; ILC, invasive lobular carcinoma.

in this study are only a molecular subtype estimation. Due to HER2 status only being available after 2010 in the SEER database, this resulted in a lack of samples and insufficient follow-up in the present study.

As research on TNBC progresses, patients with the T1-2N1M0 subtype, which has no therapeutic targets to date, may benefit from radiotherapy, although guidelines and current international consensuses do not recommend the routine use of PMRT for patients with this subtype (19,32). Clinical trials should be conducted to validate the effectiveness of radiotherapy after mastectomy in patients with T1-2N1M0 TNBC.

In conclusion, patients with T1-2N1M0 TNBC can benefit from PMRT. Despite limitations, the findings of the current study will help clinicians identify patients with T1-2N1M0 breast cancer who may benefit from PMRT.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the SSER repository (https://seer.cancer.gov/).

Authors' contributions

XW, YX and LZ made substantial contributions to the conception, design and acquisition of data. SG was involved in collecting data, drafting the manuscript and revising it critically for important intellectual content. YX, SG and MA made substantial contributions to the acquisition, analysis and interpretation of data. LZ, PC, SW, HT and JZ contributed to the data analysis. LZ, SW, PC, MA, HT and JZ revised the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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