Racial disparities in health insurance, triple-negative breast cancer diagnosis, tumor stage, treatment and survival in a large nationwide SEER cohort in the United States

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Abstract. It remains unclear whether there are racial disparities in mortality between women of different races who have the same subtype of breast cancer when tumor stage and size and treatment are controlled for. The present study aimed to investigate whether racial disparities in mortality existed between women of different races who had the same subtype of breast cancer when health insurance, tumor stage and size and treatment were controlled for in a large cohort of women with breast cancer in the United States. This study identified 399,564 women who were diagnosed with incident breast cancer at age ≥20 years between 2010 and 2016 in 17 Surveillance, Epidemiology and End Results (SEER) registries, including 277,319 non-Hispanic white (white), 44,149 non-Hispanic black (black), 34,141 non-Hispanic Asian or Pacific Islander (Asian) and 43,955 Hispanic women. White and Asian women exhibited a lower proportion of triple-negative breast cancer (9.8 and 9.1% respectively) than black (20.8%) and Hispanic women (12.6%). Black women had a significantly higher risk of all-cause mortality compared with white women in only those with triple-negative breast cancer (hazard ratio: 1.39, 95% CI: 1.29-1.51) and those with hormone receptor-negative/human epidermal growth factor receptor 2 (HER2)-positive breast cancer (1.53, 1.48-1.58) after adjusting for confounders. In those with hormone receptor-positive breast cancer, regardless of HER2 receptor status, the risk of all-cause mortality was not statistically different between black and white women, while the risk of breast cancer-specific mortality was significantly higher in all subtypes of breast cancer among black women. There were racial disparities in the presentation of triple-negative breast cancer and in all-cause and breast cancer specific mortality following stratification by triple-negative status and adjusting for tumor stage, size, grade and treatment.

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Introduction

It has been well documented that there are substantial racial disparities in cancer stage at diagnosis, treatment and survival for women with breast cancer (1-14). Poorer socioeconomic status and lack of health insurance contributes to delayed cancer screening and medical consultation, leading to later stage at diagnosis and missed opportunity for early intervention (5-14). Late diagnosis and lack of adequate treatment lead to poorer health outcomes, such as shortened survival rate and higher mortality (12-14). However, subtypes of breast cancer and pathological indicators, such as estrogen and progestin and human epidermal growth factor receptor 2 (HER2) receptor status, may not be associated with poorer socioeconomic and health insurance status. Numerous studies have shown substantial differences in presentation of these subtypes [HER2-, hormone receptor (HR)- and triple-negative] of breast cancer between women of different races; for example, African American and sub-Saharan African women exhibit a higher proportion of triple-negative breast cancer, which may suggest genetic components and hereditary susceptibility for certain types of cancer (15-24). As documented in previous studies, survival rate varies by subtypes of breast cancer, tumor stage and size, and recommended treatment, which are key factors in addressing racial disparity in survival (9-12,15-24). Cancer subtype, late stage at diagnosis and lack of adequate treatment appear to be the primary reasons for higher mortality and lower survival in African American compared with Caucasian and Asian women with breast cancer (25-30). Nevertheless, it remains unclear whether there are racial disparities in mortality between women of different races who have the same subtype of breast cancer when tumor stage and size and treatment are controlled for (28-30). The present study aimed to investigate this in a large cohort of women with breast cancer in the United States, as well as the mortality difference between non-Hispanic black and white, Asian and Hispanic women with breast cancer, controlling for differences in health

insurance, socioeconomic status, tumor stage at diagnosis, grade, size, subtype and treatment.

Materials and methods

Data sources. The National Cancer Institute Surveillance, Epidemiology and End Results (SEER) Public Use Data Set released in November 2018 was used (31). The SEER program comprises population-based tumor registries in nine areas (San Francisco/Oakland, San Jose-Monterey, Los Angeles, Greater California, Detroit, Seattle, Atlanta and Rural and Greater Georgia) and 8 states (Connecticut, Iowa, New Mexico, Utah, Hawaii, Louisiana, Kentucky and New Jersey), accounting for 28% of the U.S. population. The SEER registries ascertain all newly diagnosed (incident) cancer cases from multiple sources. Information includes tumor location, size, histological type and grade; demographic characteristics such as age, sex, race and marital status, and type of treatment provided in the first course of therapy within four months of initial therapy following diagnosis. The SEER dataset also includes information on the type of surgical procedure and use of radiation therapy and chemotherapy (yes or no/unknown). The SEER program frequently performs quality control, including case finding, reliability, missing data items, reporting delays and the quality of vital status data. The program has also developed inter- and intra-field edits to identify and correct errors in the SEER data (31). The present study received approval from SEER after signing the SEER Research Data Agreement and also received additional approval for using data on radiation therapy and chemotherapy. This study was considered exempt for Institutional Review Board review because it did not involve any patient contact and only had the analysis of the existing de-identified SEER Public Use Data.

Study population. The present study identified 404,608 women diagnosed with incident breast cancer at age ≥20 years between January 2010 (the point from which triple-negative breast cancer data were available) and December 2016 in 17 SEER registries. Of the 404,608 women with breast cancer, 2,798 women of unknown race and 2,246 native American were excluded due to small numbers. Hence, the final analysis identified 399,564 women with breast cancer, including 277,319 non-Hispanic white (white), 44,149 non-Hispanic black (black), 34,141 non-Hispanic Asian/Pacific Islander (Asian) and 43,955 Hispanic women (comprising 42,484 white and 1,471 other Hispanics, which are included in certain analyses separately).

Race/ethnicity and sociodemographic variables. Race/ethnicity was classified into white, black, Asian, Hispanic white and Hispanic other. Other patient demographics included age at diagnosis (<45, 45-54, 55-64, 65-74, 75-84 and ≥85 years), marital status (married, unmarried, unknown), year of diagnosis (2010 to 2016) and geographic area (17 SEER registries). Socioeconomic variables included individual health insurance (insured, Medicaid, uninsured and unknown) and median household income in the county level (available in the SEER*Stat program, seer.cancer.gov/seerstat/; <49,000, 49,000-57,579, 57,580-68,649 and ≥$68,650).

Tumor characteristics. Tumor characteristics included histological stage (local, regional, distant or unknown), grade (well, moderately or poorly differentiated, undifferentiated or unknown), size (<1.0, 1.0-1.9, 2.0-2.9, 3.0-3.9, ≥4.0 cm or unknown) and subtype of breast cancer based on HR and *HER2* status: HR+/HER2+ (Luminal B), HR+/HER2-(Luminal A), HR-/HER2+ (HER2 enriched) and HR-/HER2-(triple-negative).

Treatment for breast cancer. Cancer-directed surgery was categorized as either total mastectomy or breast-conserving surgery. Breast-conserving surgery was defined as segmental mastectomy, lumpectomy, quadrantectomy, tylectomy, wedge resection, nipple resection, excisional biopsy or partial mastectomy unspecified. Radiation therapy included beam radiation, radioactive implant, brachytherapy, radioisotope or other radiation, and was coded as yes or no/unknown (31). Chemotherapy was also coded as either yes or no/unknown. These treatment variables were coded separately in SEER registries; it was unknown if radiation therapy or chemotherapy were given before surgery, as adjuvant therapy after surgery or as stand-alone treatment.

Survival and mortality. The vital status (dead or alive), cause and date of death and survival time in months from date of diagnosis to the date of death or the date of last follow-up (December 31, 2016) were obtained from the SEER*Stat data (31). All-cause mortality was defined as death with any underlying cause indicated in the SEER data. Patients who were alive at the last date of follow-up were censored. Breast cancer-specific mortality was defined as breast cancer as the underlying cause of death. Patients who died of causes other than breast cancer or who were still alive at the date of last follow-up were censored.

Statistical analysis. Differences in distribution of baseline characteristics between racial/ethnic groups were tested using χ^2. Logistic regression models were used to assess the odds ratio of diagnosis at early tumor stage (local stage), having triple-negative breast cancer and receiving cancer-directed treatment (surgery, radiation therapy and chemotherapy) after adjusting for confounding factors, including age, marital status, socioeconomic status (health insurance and household income), tumor stage, grade, size, geographic SEER area and year of diagnosis. The time to event Cox proportional hazard regression model was applied in survival analysis using Proportional Hazard Regression procedure available in the SAS system version 9.4 (SAS Institute, Inc). The proportionality assumption was considered to be satisfied when log-log Kaplan-Meier curves for survival function by race/ethnicity and subtype of breast cancer were parallel and did not intersect. In these Cox proportional hazard regression analyses, two models were presented. The first model was an unadjusted hazard ratio of mortality; the second full model adjusted for patient demographic (including age and marital status), socioeconomic status (health insurance and household income), tumor characteristic (such as stage, grade and size), cancer-directed treatment (surgery, radiation therapy, and chemotherapy), geographic area and year of diagnosis.

Table I. Patient and tumor characteristics in women diagnosed with breast cancer by race/ethnicity, 2010-2016.

Characteristic	Number of cases (%)					P-value
	NH white	NH black	NH Asian	Hispanic white	Hispanic other	
Age, years						<0.001
<45	22,814.0 (8.2)	5,996.0 (13.6)	5,343.0 (15.6)	7,816.0 (8.4)	282.0 (19.2)	
45-54	51,741.0 (18.7)	10,302.0 (23.3)	8,711.0 (25.5)	11,351.0 (26.7)	403.0 (27.4)	
55-64	71,755.0 (25.9)	12,353.0 (28.0)	9,119.0 (26.7)	10,657.0 (25.1)	371.0 (25.2)	
65-74	72,836.0 (26.3)	9,310.0 (21.1)	6,910.0 (20.2)	7,909.0 (18.6)	263.0 (17.9)	
75-84	42,222.0 (15.2)	4,686.0 (10.6)	3,086.0 (9.0)	3,693.0 (8.7)	121.0 (8.2)	
≥85	15,951.0 (5.8)	1,502.0 (3.4)	972.0 (2.9)	1,058.0 (2.5)	31.0 (2.1)	
Marital status						<0.001
Married	155,910.0 (56.2)	14,708.0 (33.3)	21,674.0 (63.5)	22,778.0 (53.6)	710.0 (48.3)	
Unmarried	107,091.0 (38.6)	26,784.0 (60.7)	10,799.0 (31.6)	17,381.0 (40.9)	655.0 (44.5)	
Unknown	14,318.0 (5.2)	2,657.0 (6.0)	1,668.0 (4.9)	2,325.0 (5.5)	106.0 (7.2)	
Health insurance						
Uninsured	2,773.0 (1.0)	1,290.0 (2.9)	585.0 (1.7)	1,515.0 (3.6)	56.0 (3.8)	
Medicaid	20,206.0 (7.3)	8,680.0 (19.7)	5,007.0 (14.7)	11,069.0 (26.1)	249.0 (16.9)	
Insured	249,130.0 (89.8)	33,272.0 (75.4)	27,976.0 (81.9)	29,186.0 (68.7)	1,124.0 (76.4)	
Unknown	5,210.0 (1.9)	907.0 (2.1)	573.0 (1.7)	714.0 (1.7)	42.0 (2.9)	
Household income at county level, $						
19,340-51,269	73,872.0 (26.6)	17,263.0 (39.1)	1,459.0 (4.3)	7,331.0 (17.3)	180.0 (12.2)	
51,270-58,2549	59,866.0 (21.6)	13,512.0 (30.6)	9,728.0 (28.5)	16,476.0 (38.8)	497.0 (33.8)	
58,250-70,5769	73,606.0 (26.5)	7,690.0 (17.4)	5,722.0 (16.8)	9,579.0 (22.6)	333.0 (22.6)	
≥70,570	69,975.0 (25.2)	5,684.0 (12.9)	17,232.0 (50.5)	9,098.0 (21.4)	461.0 (31.3)	
Tumor stage						<0.001
Local	186,400.0 (67.2)	25,105.0 (56.9)	22,345.0 (65.5)	24,895.0 (58.6)	832.0 (56.6)	
Regional	75,432.0 (27.2)	15,201.0 (34.4)	9,972.0 (29.2)	14,989.0 (35.3)	527.0 (35.8)	
Distant	13,937.0 (5.0)	3,531.0 (8.0)	1,575.0 (4.6)	2,279.0 (5.4)	97.0 (6.6)	
Unknown	1,550.0 (0.6)	312.0 (0.7)	249.0 (0.7)	321.0 (0.8)	15.0 (1.0)	
Tumor size, cm						
<1.0	60,982.0 (22.0)	6,916.0 (15.7)	6,664.0 (19.5)	6,929.0 (16.3)	257.0 (17.5)	<0.001
1.0-1.9	97,245.0 (35.1)	13,025.0 (29.5)	10,645.0 (31.2)	13,093.0 (30.8)	435.0 (29.6)	
2.0-2.9	51,161.0 (18.5)	8,783.0 (19.9)	7,117.0 (20.9)	8,886.0 (20.9)	287.0 (19.5)	
3.0-3.9	23,423.0 (8.5)	4,938.0 (11.2)	3,506.0 (10.3)	4,564.0 (10.7)	164.0 (11.2)	
≥4.0	36,588.0 (13.2)	8,773.0 (19.9)	5,250.0 (15.4)	7,350.0 (17.3)	258.0 (17.5)	
Unknown	7,920.0 (2.9)	1,714.0 (3.9)	959.0 (2.8)	1,662.0 (3.9)	70.0 (4.8)	

Table I. Continued.

Characteristic	Number of cases (%)					P-value
	NH white	NH black	NH Asian	Hispanic white	Hispanic other	
Tumor grade						<0.001
Well differentiated (I)	67,563.0 (24.4)	6,243.0 (14.1)	6,810.0 (20.0)	7,938.0 (18.7)	232.0 (15.8)	
Moderately differentiated (II)	121,582.0 (43.8)	16,061.0 (36.4)	14,797.0 (43.3)	17,594.0 (41.4)	582.0 (39.6)	
Poorly (III)/undifferentiated (IV)	76,119.0 (27.5)	19,230.0 (43.6)	11,046.0 (32.4)	15,080.0 (35.5)	574.0 (39.0)	
Unknown	12,055.0 (4.4)	2,615.0 (5.9)	1,488.0 (4.4)	1,872.0 (4.4)	83.0 (5.6)	
Triple-negative status						<0.001
HR+/HER2+ (Luminal B)	27,904.0 (10.1)	5,065.0 (11.5)	4,229.0 (12.4)	5,270.0 (12.4)	195.0 (12.3)	
HR+/HER2-(Luminal A)	211,344.0 (76.2)	27,279.0 (61.8)	24,571.0 (71.9)	29,459.0 (69.3)	990.0 (67.3)	
HR-/HER2+ (HER2-enriched)	10,924.0 (3.9)	2,603.0 (5.9)	2,220.0 (6.5)	2,430.0 (5.7)	91.0 (6.2)	
HR-/HER2-(triple-negative)	27,147.0 (9.8)	9,202.0 (20.8)	3,121.0 (9.1)	5,325.0 (12.5)	195.0 (13.3)	
Total	277,319.0	44,149.0	34,141.0	42,484.0	1,471.0	

P-values were determined by χ^2 test. NH, non-Hispanic; HR, hormone receptor; HER2, human epidermal growth factor receptor 2.

Results

Patient and tumor characteristics by race/ethnicity. Table I presents the patient demographics, socioeconomic factors and tumor characteristics in each racial/ethnic group. There were notable differences in the proportion of women diagnosed with breast cancer at younger age (<45 years); a larger percentage of white patients were diagnosed at older age, whereas larger percentages of women of other races were diagnosed with breast cancer at younger age. The proportion of patients who were married, insured or living in counties with higher household incomes was greater in white and Asian compared with black and Hispanic patients. Black and Hispanic women were more likely to exhibit higher tumor stage at diagnosis, larger tumor size and poorer tumor grade, as well as triple-negative breast cancer, than white and Asian women. Overall, 11.3% of women with breast cancer were triple-negative but the proportion of triple-negative breast cancer varied by race/ethnicity (9.1 for Asian, and 9.8 for white, 12.5 for Hispanic white, 13.3 for Hispanic other and 20.8% for black women).

Percentage of early stage and triple-negative breast cancer by race/ethnicity. Table II presents the number and percentage of patients diagnosed with early (local) stage and triple-negative breast cancer by race/ethnicity, age, marital status, health insurance and household income. White and Asian women were more likely to be diagnosed with early (local) stage breast cancer (67.2 and 65.5%, respectively) compared with black (56.9), Hispanic white (58.6) and Hispanic other patients (56.6%). White and Asian women also had a notably lower proportion of triple-negative breast cancer (9.8 and 9.1% respectively) than black (20.8), Hispanic white (12.5) and Hispanic other patients (13.3%). Older, married, insured women and those living in counties with higher household income were more likely to be diagnosed with early (local) stage breast cancer. However, a higher percentage of triple-negative breast cancer was observed in younger and unmarried women, as well as those with no health insurance and those living in counties with low median household incomes. Diagnosis of early stage breast cancer was associated with smaller tumor size and better tumor grade; there was no notable association between triple-negative breast cancer and tumor size and grade. In addition, racial disparities in rates of triple-negative breast cancer from 2010 to 2016 were analyzed. The rate of triple-negative breast cancer decreased from 10.7 in 2010 to 8.8% in 2016 in white women and from 22.1 in 2010 to 19.6% in 2016 in black women. The rate of triple-negative breast cancer also decreased from 9.8 to 8.5% for Asian and from 14.7 to 11.6% Hispanic white women, but increased from 13.1 to 17.5% for Hispanic other.

Odds ratios of early stage, triple-negative cancer and treatment by race/ethnicity. Table III presents the adjusted odds ratios of patients being diagnosed with early (local) stage and with triple-negative breast cancer and the adjusted odds ratios of receiving cancer-directed surgery, chemotherapy and radiation therapy by race/ethnicity, age, marital status, health insurance, household income, tumor stage, tumor size, and tumor grade. Black and Hispanic women were significantly less likely to be diagnosed with early (local) stage breast

Table II. Association between tumor stage and triple-negative diagnosis and socioeconomic status and race/ethnicity.

	Tumor stage (%)		Triple-negative status (%)			
Characteristic	Local	Higher	HR+/HER2+	HR+/HER2-	HR-/HER2+	HR-/HER2-(triple-negative)
Race/ethnicity						
NH white	186,400.0 (67.2)	90,919.0 (32.8)	27,904.0 (10.1)	211,344.0 (76.2)	10,924.0 (3.9)	27,147.0 (9.8)
NH black	25,105.0 (56.9)	19,044.0 (43.1)	5,065.0 (11.5)	27,279.0 (61.8)	2,603.0 (5.9)	9,202.0 (20.8)
NH Asian	22,345.0 (65.5)	11,796.0 (34.6)	4,229.0 (12.4)	24,571.0 (72.0)	2,220.0 (6.5)	3,121.0 (9.1)
Hispanic white	24,895.0 (58.6)	17,589.0 (41.4)	5,270.0 (12.4)	29,459.0 (69.3)	2,430.0 (5.7)	5,325.0 (12.5)
Hispanic other	832.0 (56.6)	639.0 (43.4)	195.0 (13.3)	990.0 (67.3)	91.0 (6.2)	195.0 (13.3)
Age, years						
<45	21,893.0 (51.8)	20,358.0 (48.2)	7,021.0 (16.6)	25,495.0 (60.3)	2,693.0 (6.4)	7,042.0 (16.7)
45-54	50,025.0 (60.6)	32,483.0 (39.4)	10,396.0 (12.6)	57,284.0 (69.4)	4,611.0 (5.6)	10,217.0 (12.4)
55-64	67,848.0 (65.1)	36,407.0 (34.9)	11,437.0 (11.0)	75,773.0 (72.7)	5,297.0 (5.1)	11,748.0 (11.3)
65-74	68,945.0 (70.9)	28,283.0 (29.1)	8,150.0 (8.4)	76,547.0 (78.7)	3,317.0 (3.4)	9,214.0 (9.5)
75-84	37,991.0 (70.6)	15,817.0 (29.4)	4,075.0 (7.6)	43,145.0 (80.2)	1,702.0 (3.2)	4,886.0 (9.1)
≥85	12,875.0 (66.0)	6,639.0 (34.0)	1,584.0 (8.1)	15,399.0 (78.9)	648.0 (3.3)	1,883.0 (9.7)
Marital status						
Married	143,052.0 (66.3)	72,728.0 (33.7)	23,555.0 (10.9)	158,792.0 (73.6)	9,982.0 (4.6)	23,451.0 (10.9)
Unmarried	102,982.0 (63.3)	59,728.0 (36.7)	16,968.0 (10.4)	119,249.0 (73.3)	7,323.0 (4.5)	19,170.0 (11.8)
Unknown	13,543.0 (64.3)	7,531.0 (35.7)	2,140.0 (10.2)	15,602.0 (74.0)	963.0 (4.6)	2,369.0 (11.2)
Health insurance						
Uninsured	2,994.0 (48.1)	3,225.0 (51.9)	864.0 (13.9)	3,947.0 (63.5)	408.0 (6.6)	1,000.0 (16.1)
Medicaid	24,143.0 (53.4)	21,068.0 (46.6)	5,713.0 (12.6)	30,265.0 (66.9)	2,830.0 (6.3)	6,403.0 (14.2)
Insured	227,784.0 (66.9)	112,904.0 (33.1)	35,333.0 (10.4)	253,879.0 (74.5)	14,698.0 (4.3)	36,778.0 (10.8)
Unknown	4,656.0 (62.5)	2,790.0 (37.5)	753.0 (10.1)	5,552.0 (74.6)	332.0 (4.5)	809.0 (10.9)
Household income at county level, $						
19,340-51,269	63,663.0 (63.6)	36,442.0 (36.4)	10,882.0 (10.9)	71,143.0 (71.1)	4,857.0 (4.9)	13,223.0 (13.2)
51,270-58,2549	63,557.0 (63.5)	36,522.0 (36.5)	11,073.0 (11.1)	72,628.0 (72.6)	4,784.0 (4.8)	11,594.0 (11.6)
58,250-70,5769	63,211.0 (65.2)	33,719.0 (34.8)	10,153.0 (10.5)	72,292.0 (74.6)	4,171.0 (4.3)	10,314.0 (10.6)
≥70,570	69,146.0 (67.5)	33,304.0 (32.5)	10,555.0 (10.3)	77,580.0 (75.7)	4,456.0 (4.4)	9,859.0 (9.6)
Tumor stage						
Local	259,577.0 (100.0)	0.0 (0.0)	23,668.0 (9.1)	199,549.0 (76.9)	9,118.0 (3.5)	27,242.0 (10.5)
Regional	0.0 (0.0)	116,121.0 (100.0)	15,174.0 (13.1)	79,475.0 (68.4)	7,102.0 (6.1)	14,370. (12.4)
Distant	0.0 (0.0)	21,419.0 (100.0)	3,528.0 (16.5)	12,908.0 (60.3)	1,923.0 (8.9)	3,060.0 (14.3)
Unknown	0.0 (0.0)	2,447.0 (100.0)	293.0 (12.0)	1,711.0 (69.9)	125.0 (5.1)	318.0 (13.0)

Table II. Continued.

Characteristic	Tumor stage (%)		Triple-negative status (%)			
	Local	Higher	HR+/HER2+	HR+/HER2-	HR-/HER2+	HR-/HER2-(triple-negative)
Tumor size, cm						
<1.0	73,816.0 (90.3)	7,932 (9.7)	6,292.0 (7.7)	67,114.0 (82.1)	2,810.0 (3.44)	5,532.0 (6.8)
1.0-1.9	103,804.0 (77.2)	30,639.0 (22.8)	12,111.0 (9.0)	106,481.0 (79.2)	3,876.0 (2.9)	11,975.0 (8.9)
2.0-2.9	44,548.0 (58.4)	31,686.0 (41.6)	9,111.0 (11.9)	53,409.0 (70.1)	3,601.0 (4.7)	10,113.0 (13.3)
3.0-3.9	16,456.0 (45.0)	20,139.0 (55.0)	5,005.0 (13.7)	23,253.0 (63.5)	2,250.0 (6.2)	6,087.0 (16.6)
≥4.0	17,516.0 (30.1)	40,703.0 (69.9)	8,339.0 (14.3)	35,706.0 (61.3)	4,623.0 (7.9)	9,551.0 (16.4)
Unknown	3,437.0 (27.9)	8,888.0 (72.1)	1,805.0 (14.6)	7,680.0 (62.3)	1,108.0 (9.0)	1,732.0 (14.1)
Tumor grade						
Well differentiated	112,650.0 (66.0)	57,966.0 (34.0)	17,032.0 (9.9)	141,721.0 (83.1)	4,105.0 (2.4)	7,758.0 (4.6)
Moderately differentiated	65,863.0 (54.0)	56,186.0 (46.0)	20,522.0 (16.8)	55,038.0 (45.1)	12,481.0 (10.2)	34,008.0 (27.9)
Poorly/undifferentiated	8,380.0 (46.3)	9,733.0 (53.7)	2,401.0 (13.3)	12,006.0 (66.3)	1,433.0 (7.9)	2,273.0 (12.5)
Unknown	72,684.0 (81.9)	16,102.0 (18.1)	2,708.0 (3.1)	84,878.0 (95.6)	249.0 (0.3)	951.0 (1.1)
Total	259,577.0 (100.0)	139,987.0 (100.0)	42,663.0 (100.0)	293,643.0 (100.0)	18,268.0 (100.0)	44,990.0 (100.0)

NH, non-Hispanic; HR, hormone receptor; HER2, human epidermal growth factor receptor 2.

Table III. Adjusted odds ratio of diagnosis of early stage breast cancer, triple-negative status and treatment by race/ethnicity, age, socioeconomic status and certain tumor characteristics.

Characteristic	Local stage (95% CI)	Triple-negative (95% CI)	Cancer-directed surgery (95% CI)	Radiation therapy (95% CI)	Chemotherapy (95% CI)
Race/ethnicity					
NH white	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
NH black	0.90 (0.88-0.92)[a]	1.78 (1.72-1.83)[a]	0.71 (0.68-0.74)[a]	0.96 (0.94-0.98)[a]	1.12 (1.09-1.15)[a]
NH Asian	1.09 (1.06-1.12)[a]	0.80 (0.77-0.84)[a]	0.91 (0.86-0.96)[a]	0.84 (0.82-0.86)[a]	0.99 (0.96-1.03)
Hispanic white	0.90 (0.88-0.92)[a]	1.10 (1.06-1.14)[a]	0.92 (0.88-0.97)[a]	0.95 (0.93-0.97)[a]	1.12 (1.08-1.15)[a]
Hispanic other	0.82 (0.73-0.93)[a]	1.09 (0.93-1.29)	0.87 (0.70-1.07)	0.98 (0.88-1.09)	1.05 (0.93-1.20)
Age, years					
<45	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
45-54	1.15 (1.12-1.18)[a]	0.90 (0.87-0.94)[a]	0.99 (0.95-1.06)	1.14 (1.12-1.17)[a]	0.62 (0.60-0.64)[a]
55-64	1.29 (1.26-1.32)[a]	0.89 (0.86-0.92)[a]	0.91 (0.86-0.96)[a]	1.33 (1.30-1.37)[a]	0.44 (0.42-0.45)[a]
65-74	1.52 (1.48-1.57)[a]	0.88 (0.84-0.91)[a]	0.82 (0.77-0.86)[a]	1.21 (1.18-1.24)[a]	0.24 (0.23-0.25)[a]
75-84	1.64 (1.59-1.69)[a]	0.86 (0.83-0.90)[a]	0.49 (0.47-0.52)[a]	0.73 (0.71-0.75)[a]	0.06 (0.06-0.07)[a]
≥85	1.81 (1.74-1.89)[a]	0.83 (0.78-0.88)[a]	0.16 (0.15-0.17)[a]	0.25 (0.24-0.26)[a]	0.01 (0.01-0.01)[a]
Marital status					
Married	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Unmarried	0.97 (0.96-0.99)[a]	0.99 (0.96-1.01)	0.75 (0.73-0.78)[a]	0.89 (0.88-0.91)[a]	0.86 (0.84-0.87)[a]
Unknown	1.02 (0.98-1.05)	1.02 (0.97-1.07)	0.59 (0.55-0.62)[a]	0.75 (0.73-0.77)[a]	0.81 (0.78-0.84)[a]
Health insurance					
Uninsured	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Medicaid	1.07 (1.00-1.13)[a]	0.89 (0.82-0.96)[a]	1.69 (1.54-1.84)[a]	1.01 (0.95-1.06)	0.99 (0.93-1.06)
Insured	1.29 (1.21-1.36)[a]	0.89 (0.83-0.96)[a]	2.56 (2.35-2.79)[a]	1.16 (1.10-1.22)[a]	1.18 (1.11-1.26)[a]
Unknown	1.37 (1.27-1.49)[a]	0.84 (0.76-0.94)[a]	1.13 (1.01-1.26)[a]	0.69 (0.64-0.75)[a]	0.63 (0.57-0.69)[a]
Household income at county level, $					
19,340-51,269	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
51,270-58,2549	1.02 (0.99-1.05)	0.96 (0.93-0.99)[a]	0.92 (0.88-0.97)[a]	1.05 (1.03-1.08)[a]	0.94 (0.91-0.97)[a]
58,250-70,5769	1.00 (0.98-1.03)	0.93 (0.89-0.97)[a]	0.86 (0.81-0.90)[a]	1.08 (1.06-1.11)[a]	0.96 (0.93-0.99)[a]
≥70,570	1.10 (1.07-1.14)[a]	0.84 (0.81-0.88)[a]	0.76 (0.72-0.80)[a]	1.02 (0.99-1.04)	0.87 (0.84-0.90)[a]
Tumor stage					
Local	-	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Regional	-	0.70 (0.68-0.71)[a]	0.74 (0.72-0.77)[a]	1.40 (1.38-1.43)[a]	4.65 (4.56-4.74)[a]
Distant	-	0.69 (0.66-0.73)[a]	0.03 (0.03-0.03)[a]	0.66 (0.64-0.68)[a]	2.42 (2.33-2.51)[a]
Unknown	-	0.93 (0.81-1.06)	0.08 (0.07-0.09)[a]	0.36 (0.32-0.41)[a]	0.79 (0.71-0.89)[a]
Tumor size, cm					
<1.0	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
1.0-1.9	0.39 (0.38-0.40)[a]	0.95 (0.91-0.98)[a]	0.94 (0.89-0.99)[a]	0.99 (0.97-1.01)	1.91 (1.86-1.96)[a]
2.0-2.9	0.18 (0.17-0.18)[a]	1.06 (1.02-1.10)[a]	0.68 (0.64-0.71)[a]	0.78 (0.76-0.80)[a]	2.96 (2.88-3.04)[a]
3.0-3.9	0.11 (0.10-0.11)[a]	1.23 (1.18-1.29)[a]	0.45 (0.43-0.48)[a]	0.69 (0.67-0.71)[a]	3.65 (3.52-3.77)[a]
≥4.0	0.05 (0.05-0.05)[a]	1.29 (1.24-1.34)[a]	0.39 (0.37-0.41)[a]	0.82 (0.79-0.84)[a]	3.73 (3.62-3.85)[a]
Unknown	0.05 (0.05-0.05)[a]	1.28 (1.19-1.36)[a]	0.10 (0.09-0.10)[a]	0.52 (0.49-0.55)[a]	2.49 (2.36-2.63)[a]
Tumor grade					
Well differentiated	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Moderately differentiated	0.60 (0.59-0.61)[a]	4.44 (4.15-4.76)[a]	0.93 (0.89-0.97)[a]	0.91 (0.89-0.93)[a]	2.50 (2.44-2.57)[a]
Poorly/undifferentiated	0.53 (0.52-0.54)[a]	34.65 (32.43-37.02)[a]	1.02 (0.98-1.07)	0.83 (0.82-0.85)[a]	9.39 (9.15-9.64)[a]
Unknown	0.39 (0.37-0.40)[a]	12.83 (11.85-13.89)[a]	0.28 (0.27-0.30)[a]	0.74 (0.72-0.77)[a]	3.05 (2.92-3.18)[a]

Adjusted for race/ethnicity, age, marital status, insurance, income, tumor stage, size, grade, year of diagnosis and SEER area. [a]P<0.05. NH, non-Hispanic.

Table IV. Observed survival rate by race/ethnicity, stratified by tumor stage and triple-negative status.

Characteristic	Overall survival				Breast cancer-specific survival		
	Median survival 2010-2016, months	Observed survival 2010-2016, %	1-year survival 2010-2015, %	3-year survival 2010-2013, %	Observed survival 2010-2016, %	1-year survival 2010-2015, %	3-year survival 2010-2013, %
Race/ethnicity							
NH white	34	88.3	96.3	89.1	93.9	97.8	93.9
NH black	30	83.0	93.9	82.7	88.8	95.9	88.2
NH Asian	31	92.7	97.5	92.8	95.4	98.5	95.4
Hispanic white	29	90.1	97.1	90.4	93.4	98.1	93.3
Hispanic other	30	88.1	95.7	88.5	91.7	97.4	91.7
Triple-negative status							
HR+/HER2+	31	89.0	96.3	89.4	93.2	97.6	93.3
HR+/HER2-	34	89.9	97.0	90.8	95.1	98.4	95.3
HR-/HER2+	30	84.6	93.9	84.2	88.9	95.5	88.1
HR-/HER2- (triple-negative)	29	78.8	91.7	78.1	84.6	93.9	83.5

NH, non-Hispanic; HR, hormone receptor; HER2, human epidermal growth factor receptor 2.

cancer, whereas Asian women were significantly more likely to be diagnosed with early stage breast cancer as compared to white women. Black (odds ratio: 1.78, 95% CI: 1.72-1.83) and Hispanic white women (1.10, 1.06-1.14) were also significantly more likely to be diagnosed with triple-negative breast cancer, whereas Asian women (0.80, 0.77-0.84) were significantly less likely to be diagnosed with triple-negative breast cancer as compared to white women. All other ethnic groups of women appeared to be significantly less likely to receive cancer-directed surgery and radiation therapy than white women with breast cancer, while black and Hispanic white women were significantly more likely to receive chemotherapy.

Early stage breast cancer was significantly more common in older and insured women and was significantly associated with smaller tumor size and better tumor grade (Table III). This was observed in all races/ethnicities in stratified analyses. Triple-negative breast cancer was significantly less common in older and insured women and was significantly associated with increased tumor size and poorer tumor grade. Early stage tumor at diagnosis was less common in unmarried women but triple-negative breast cancer was not significantly associated with marital status. Early stage tumor was not associated with household income at county level, but triple-negative breast cancer was slightly less common in those with higher household income. For cancer treatment, older women were less likely to receive surgery and chemotherapy but more likely to receive radiation therapy than younger women; married women were significantly more likely to receive all types of cancer therapy. Similarly, insured women were significantly more likely to receive all types of cancer therapy than those without health insurance, while those living in higher household income counties were slightly less likely to receive surgery and chemotherapy but more likely to receive radiation therapy than those in the lowest income quartile. The odds ratio of receiving surgery and radiation therapy decreased with higher tumor stage, larger tumor size and poorer tumor grade, but odds ratio of receiving chemotherapy increased significantly with higher tumor stage, larger tumor size and poorer tumor grade. Cancer-directed therapy was compared based on triple-negative status. Patients with HR+/HER2+ (Luminal B), HR+/HER2- (Luminal A), HR-/HER2+ (HER2-enriched) and HR-/HER2 (triple-negative) received surgery in 87.9, 92.2, 85.6 and 89.5, radiation therapy in 44.7, 50.5, 41.5 and 45.6 and chemotherapy in 70.7, 28.4, 75.2 and 72.1% of cases, respectively (data not shown). The percentage of patients with triple-negative breast cancer receiving cancer-directed surgery and radiotherapy was not significantly different from patients with other types of breast cancer. However, patients with triple-negative breast cancer were more likely to receive chemotherapy than patients with HR+/HER2- (Luminal A) breast cancer.

Median survival rate by race/ethnicity. Table IV presents the association between observed median survival and 1- and 3-year rates for overall and breast cancer-specific survival with race/ethnicity and triple-negative status. Median survival was highest in white women and those with HR-positive and HER2-negative breast cancer, and lowest in black women and those with triple-negative breast cancer. The observed 1- and 3-year and total observed survival rates were highest in Asian women and those with HR-positive and HER2-negative breast cancer and lowest in black women and those with triple-negative breast cancer.

Hazard ratio of mortality by race/ethnicity. Table V presents the crude and adjusted hazard ratios of all-cause and breast cancer-specific mortality by race/ethnicity, tumor stage and triple-negative status. Compared with white women, black

Table V. Risk of all-cause and breast cancer-specific mortality by race/ethnicity, adjusting for socioeconomic status, tumor stage and triple-negative status.

	Hazard ratio (95% CI) of all-cause mortality		Hazard ratio (95% CI) of breast cancer-specific mortality	
Characteristic	Crude model	Adjusted model	Crude model	Adjusted model
Race/ethnicity				
NH white	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
NH black	1.57 (1.53-1.61)[a]	1.16 (1.12-1.19)[a]	1.95 (1.89-2.02)[a]	1.19 (1.15-1.23)[a]
NH Asian	0.67 (0.64-0.69)[a]	0.77 (0.74-0.80)[a]	0.79 (0.75-0.84)[a]	0.82 (0.78-0.87)[a]
Hispanic white	0.93 (0.90-0.96)[a]	0.93 (0.90-0.96)[a]	1.19 (1.14-1.23)[a]	0.97 (0.92-1.01)
Hispanic other	1.12 (0.97-1.30)	1.10 (0.95-1.28)	1.49 (1.24-1.77)[a]	1.15 (0.96-1.38)
Tumor stage				
Local	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Regional	2.21 (1.99-2.07)[a]	1.77 (1.73-1.81)[a]	4.07 (3.95-4.21)[a]	2.83 (2.73-2.93)[a]
Distant	12.50 (12.22-12.81)[a]	5.04 (4.89-5.20)[a]	33.06 (32.00-34.16)[a]	10.22 (9.80-10.66)[a]
Unknown	6.61 (6.15-7.10)[a]	1.56 (1.45-1.69)[a]	11.04 (10.00-12.19)[a]	2.35 (2.11-2.61)[a]
Triple-negative status				
HR+/HER2+	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
HR+/HER2-	0.88 (0.86-0.91)[a]	1.07 (1.03-1.10)[a]	0.69 (0.67-0.72)[a]	1.13 (1.09-1.18)[a]
HR-/HER2+	1.44 (1.37-1.51)[a]	1.33 (1.27-1.39)[a]	1.67 (1.57-1.76)[a]	1.43 (1.36-1.52)[a]
HR-/HER2- (triple-negative)	1.99 (1.91-2.05)[a]	2.24 (2.16-2.32)[a]	2.31 (2.21-2.41)[a]	2.87 (2.74-2.99)[a]
Race stratified by triple-negative status				
HR-/HER2- (triple-negative)				
NH white	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
NH black	1.39 (1.29-1.51)[a]	1.19 (1.09-1.30)[a]	1.59 (1.45-1.76)[a]	1.25 (1.12-1.39)[a]
NH Asian	0.64 (0.56-0.72)[a]	0.79 (0.69-0.90)[a]	0.71 (0.61-0.83)[a]	0.82 (0.70-0.97)[a]
Hispanic white	0.85 (0.77-0.93)[a]	0.89 (0.81-0.99)[a]	1.09 (0.97-1.22)	1.02 (0.90-1.16)
Hispanic other	0.97 (0.63-1.51)	1.10 (0.70-1.71)	0.90 (0.50-1.63)	0.82 (0.45-1.49)
HR-/HER2+				
NH white	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
NH black	1.53 (1.48-1.58)[a]	1.19 (1.15-1.24)[a]	1.96 (1.87-2.05)[a]	1.25 (1.19-1.32)[a]
NH Asian	0.62 (0.59-0.65)[a]	0.74 (0.70-0.78)[a]	0.76 (0.71-0.82)[a]	0.80 (0.74-0.86)[a]
Hispanic white	0.88 (0.84-0.92)[a]	0.91 (0.87-0.95)[a]	1.12 (1.06-1.19)[a]	0.94 (0.89-0.99)[a]
Hispanic other	1.12 (0.93-1.36)	1.21 (0.99-1.46)	1.68 (1.34-2.12)[a]	1.40 (1.11-1.77)[a]
HR+/HER2-				
NH white	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
NH black	1.26 (1.14-1.39)[a]	1.10 (0.99-1.23)	1.42 (1.26-1.59)[a]	1.21 (1.06-1.37)[a]
NH Asian	0.67 (0.59-0.77)[a]	0.87 (0.75-1.01)	0.74 (0.63-0.87)[a]	0.93 (0.78-1.10)
Hispanic white	0.90 (0.80-1.01)	1.04 (0.92-1.19)	1.01 (0.88-1.16)	1.09 (0.94-1.27)
Hispanic other	1.11 (0.65-1.87)	1.11 (0.65-1.88)	1.59 (0.94-2.69)	1.43 (0.84-2.44)
HR+/HER2+				
NH white	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
NH black	1.23 (1.17-1.29)[a]	1.05 (0.99-1.11)	1.32 (1.24-1.40)[a]	1.08 (1.01-1.15)[a]
NH Asian	0.81 (0.74-0.88)[a]	0.84 (0.76-0.93)[a]	0.85 (0.77-0.95)[a]	0.83 (0.74-0.93)[a]
Hispanic white	0.97 (0.91-1.04)	0.92 (0.86-0.99)[a]	1.11 (1.03-1.20)[a]	0.94 (0.86-1.02)
Hispanic other	0.98 (0.71-1.36)	0.84 (0.61-1.17)	0.97 (0.65-1.43)	0.77 (0.52-1.14)

Adjusted for age, marital status, tumor stage, size, grade, year of diagnosis, SEER registry, health insurance, household income at county level, surgery, radiation and chemotherapy. [a]P<0.05. NH, non-Hispanic; HR, hormone receptor; HER2, human epidermal growth factor receptor 2.

women had a significantly higher risk of all-cause and breast cancer-specific mortality after adjusting for age, marital status, tumor stage, size, grade, year of diagnosis, SEER registry, health insurance, household income at county level, surgery,

radiation and chemotherapy. The adjusted hazard ratio of all-cause mortality was significantly lower in both Asian and Hispanic white women compared with non-Hispanic white women; the risk of breast cancer-specific mortality was significantly lower in Asian women but not significantly different in Hispanic white or other compared with white women. Table V also presents racial disparities in the crude and adjusted hazard ratios of all-cause and breast cancer-specific mortality stratified by triple-negative status. Black women had a significantly higher risk of all-cause mortality compared with white women in those with triple-negative (hazard ratio: 1.39, 95% CI: 1.29-1.51) and HR-negative/HER2-positive breast cancer (1.53, 1.48-1.58) after adjusting for confounding factors. In those with HR-positive breast cancer, regardless of HER2 receptor status, the risk of all-cause mortality was not statistically different between black and white women, while the risk of breast cancer-specific mortality was significantly higher in all subtypes of breast cancer in black compared with white women. In those with HR-positive/HER2-negative breast cancer, there was no statistically different risk of mortality across different racial/ethnical groups, except for a higher risk of breast cancer-specific mortality in black women. In patients with HR-positive/HER2-positive breast cancer, the risk of all-cause mortality was lower in Asian and Hispanic white women, while the risk of breast cancer-specific mortality was higher in black compared with non-Hispanic white women. Finally, racial disparities in mortality were analyzed over time. The adjusted hazard ratio of all-cause mortality in 2010 was signifcantly higher for black (1.13, 1.07-1.20), significantly lower for Asian (0.72, 0.65-0.79) and not signifcantly different for Hispanic white (0.94, 0.87-1.01) compared with non-Hispanic white women. However, in 2016 the adjusted hazard ratio of all-cause mortality was not signifcantly higher for black women (1.07, 0.89-1.28), but still significantly lower for Asian women (0.53, 0.38-0.74) and not signifcantly different for Hispanic white women (0.79, 0.62-1.01) with wider confidence intervals compared with non-Hispanic white women.

Discussion

The present study demonstrated that there were racial disparities in the presentation of triple-negative breast cancer and tumor stage, and all-cause mortality and breast cancer-specific mortality existed following stratification by triple-negative status and adjusting for tumor stage, size, grade, and treatment. Black women had a significantly higher risk of all-cause mortality compared with white women in only those with triple-negative and HR-negative/HER2-positive breast cancer after adjusting for confounding factors, but the risk of breast cancer-specific mortality was significantly higher in all subtypes of breast cancer in black women. The percentage of triple-negative breast cancer decreased slightly from 2010 to 2016 in women of all different races except Hispanic other. The risk of all-cause mortality between black and white women decreased slightly from 2010 to 2016, while the risk of all-cause mortality for Asian and Hispanic white women remained similar over time.

Triple-negative breast cancer has been studied extensively since 2005 (15-23) and affects 12-17% of women with breast cancer (15). This subtype of disease affected 11.3% of women with breast cancer in the present study cohort, but disproportionally affected black women (20.8%). Triple-negative breast cancer has higher incidence and poorer survival in black women (19-23); it is important to identify key causes of differential incidence rates and poorer outcomes to decrease incidence and improve survival rates. Previous studies have reported that racial and ethnic disparities in triple-negative breast cancer incidence and outcomes may be explained by biological factors, such as genetic factors and obesity, and non-biological factors such as poverty, social stress and toxic-waste dumping (19-25,32-37). In the present study cohort, black and Hispanic women were significantly less likely to be diagnosed with early (local) stage breast cancer, whereas Asian women were significantly more likely to be diagnosed with early stage breast cancer compared with white women. Black women were also significantly more likely to be diagnosed with triple-negative breast cancer after adjusting for tumor stage, health insurance and household income at the country level. Differences in demographic and tumor characteristics have been reported by other investigators (15-28,32-36). For example, Plasilova *et al* (34) reported that women with triple-negative breast cancer exhibit poorer tumor grades and are more likely to have poorly differentiated tumors. Obese or overweight women are more likely to present with triple-negative breast cancer (32,37-39). The evidence on the mechanistic link between obesity, insulin signaling, inflammation and aggressive subtypes of triple-negative breast cancer is increasing (37-40). The present study also showed that early stage breast cancer was significantly associated with older age, health insurance, smaller tumor size and better tumor grade, potentially because older women and those with health insurance are more likely to attend regular screenings (12).

It is unknown to what extent tumor and socioeconomic factors affect clinical survival outcomes of different ethnic groups (41,42). Studies from California, Georgia and North Carolina have reported racial and ethnic disparities in the clinical presentation of triple-negative breast cancer and survival rates after adjusting for confounding factors (28,29,43). An analysis of 2010-2012 SEER data also reported that patients with triple-negative breast cancer exhibit poorer survival than those with other types of breast cancer (30). The findings of the present study of SEER areas in 2010-2016 were consistent with the aforementioned studies. Black women had a significantly higher risk of all-cause and breast cancer-specific mortality compared with white women in only those with triple-negative and HR-negative/HER2-positive breast cancer after adjusting for confounding factors. In those with HR-positive breast cancer, regardless of HER2-receptor status, the risk of all-cause mortality was not statistically different between black and white women. Furthermore, in those with HR-positive/HER2-negative breast cancer, there was no statistically different risk of mortality across different racial/ethnical groups, except for a higher risk of breast cancer-specific mortality in non-Hispanic black women. Racial disparities in health care and therapy have been documented in numerous medical conditions, as reported by the Institute of Medicine (44). Racial disparities were observed in therapy and clinical outcomes in the present large nationwide and population-based SEER cohort of women with breast cancer.

Differences in cancer therapy may affect racial disparities in all-cause and breast cancer-specific mortality, but disparities in mortality remained significant in black women with triple-negative breast cancer. Certain studies have found no racial disparities in mortality in women with triple-negative breast cancer (26,27), whereas other studies showed a higher mortality in black women with triple-negative breast cancer after controlling for socioeconomic factors, treatment delay and HR/HER2 expression (28-30). Triple-negative breast cancer is a distinct invasive type of breast cancer and patients exhibit a poorer response to therapy than those with HER2- or HR-positive or tumors, leading to poorer clinical outcomes (30). Studies have shown that genetic factors may serve a role in the risk of triple-negative breast cancer through methylation and histone modification (45), which may lead to poorer survival.

Certain limitations should be noted in the present study. First, information on radiation therapy and chemotherapy from SEER data was coded as yes or no/unknown. Hence, the effects of different types of radiation therapy (such as beam radiation, radioactive implants, brachytherapy, radioisotopes or other radiation) and chemotherapy agents (such as doxorubicin, cyclophosphamide, fluorouracil or combination regimens) were not investigated. Furthermore, those who did not receive radiation therapy and chemotherapy or those with unknown status according to the SEER data may have received therapy from private clinics outside the registry. Also, information on the duration between diagnosis and treatment was not available; delayed treatment may impact survival outcomes. There was no information on comorbid conditions in the present study, hence the confounding effect of comorbidity was not assessed or controlled for. Household income at the county level was used as a measure of socioeconomic status but does not reflect individual patients, therefore ecological fallacy or bias may be present. Health insurance at an individual level was used as another measure of socioeconomic status and controlled for in regression models. Although the total number of cases was relatively large, the number of Hispanic other and cases for stratified analysis by subgroups (especially those aged ≥85 years) and the year of diagnosis was small. Furthermore, factors such as timeliness and completeness of chemotherapy or radiation therapy, treatment adherence and physical exercises were not measured. Finally, the present study did not obtain information on genetic factors, regular screening status, counseling services, general awareness and lifestyle factors. Therefore, the interaction between genetic and environmental factors on the risk and clinical outcomes of triple-negative breast cancer was not assessed.

In conclusion, there were racial disparities in the presentation of triple-negative breast cancer, tumor stage and all-cause and breast cancer specific mortality following stratification by triple-negative status and adjusting for tumor stage, size, grade and treatment. Further studies are needed to identify treatment strategies to improve outcome of patients with triple-negative breast cancer and identify key risk factors for health disparities in different ethnic groups.

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Availability of data and materials

The data that support the findings of this study are available from the National Cancer Institute SEER Program but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of SEER.

Authors' contributions

XD conceptualized and designed the study, collected and analyzed data and wrote and edited the manuscript. XD confirms the authenticity of all the raw data. XD has read and approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The author declares they have no competing interests.

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