



Original Investigation | Oncology

Association Between Residence in Historically Redlined Districts Indicative of Structural Racism and Racial and Ethnic Disparities in Breast Cancer Outcomes

Jesse J. Plascak, PhD; Kirsten Beyer, PhD; Xinyi Xu, PhD; Antoinette M. Stroup, PhD; Gabrielle Jacob, MPH; Adana A. M. Llanos, PhD, MPH

Abstract

IMPORTANCE Historical structural racism may be associated with racial, ethnic, and geographic disparities in breast cancer outcomes, but few studies have investigated these potential relationships.

OBJECTIVE To test associations among historical mortgage lending discrimination (using 1930s Home Owners' Loan Corporation [HOLC] redlining data), race and ethnicity, tumor clinicopathologic features, and survival among women recently diagnosed with breast cancer.

DESIGN, SETTING, AND PARTICIPANTS This cohort study used a population-based, state cancer registry to analyze breast tumor clinicopathology and breast cancer-specific death among women diagnosed from 2008 to 2017 and followed up through 2019. Participants included all primary, histologically confirmed, invasive breast cancer cases diagnosed among women aged at least 20 years and who resided in a HOLC-graded area of New Jersey. Those missing race and ethnicity data (n = 61) were excluded. Data were analyzed between June and December 2021.

EXPOSURES HOLC risk grades of A ("best"), B ("still desirable"), C ("definitely declining"), and D ("hazardous" [ie, redlined area]).

MAIN OUTCOMES AND MEASURES Late stage at diagnosis, high tumor grade, triple-negative subtype (lacking estrogen receptor, progesterone receptor, and human epidermal growth factor receptor 2 expression), breast cancer-specific death.

RESULTS Among a total of 14 964 women with breast cancer, 2689 were Latina, 3506 were non-Latina Black, 7686 were non-Latina White, and 1083 were other races and ethnicities (non-Latina Asian/Pacific Islander/Native American/Alaska Native/Hawaiian or not otherwise specified); there were 1755 breast cancer-specific deaths. Median follow-up time was 5.3 years (95% CI, 5.2-5.3 years) and estimated 5-year breast cancer-specific survival was 88.0% (95% CI, 87.4%-88.6%). Estimated associations between HOLC grade and each breast cancer outcome varied by race and ethnicity; compared with residence in HOLC redlined areas, residence in HOLC areas graded "best" was associated with lower odds of late-stage diagnosis (odds ratio [OR], 0.34 [95% CI, 0.22-0.53]), lower odds of high tumor grade (OR, 0.72 [95% CI, 0.57-0.91]), lower odds of triple-negative subtype (OR, 0.67 [95% CI, 0.47-0.95]), and lower hazard of breast cancer-specific death (hazard ratio, 0.48 [95% CI, 0.35-0.65]), but only among non-Latina White women. There was no evidence supporting associations among non-Latina Black or Latina women.

CONCLUSIONS AND RELEVANCE Compared with redlined areas, current residence in non-redlined areas was associated with more favorable breast cancer outcomes, but only among non-Latina White

(continued)

Key Points

Question Is historical mortgage lending discrimination (1930s redlining) associated with recent breast cancer outcomes differently by race and ethnicity?

Findings In this cohort study of 14 964 breast cancer cases, we found evidence that residence at diagnosis in areas historically graded "best" (vs residence in redlined areas) was associated with lower odds of late-stage diagnosis, lower odds of high tumor grade, lower odds of triple-negative subtype, and lower hazard of breast cancer-specific death, but only among non-Latina White women.

Meaning These findings suggest that historical structural racism may be associated with beneficial cancer outcomes among privileged racial and ethnic groups.

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

Open Access. This is an open access article distributed under the terms of the CC-BY License.

Abstract (continued)

women. Future studies should examine additional factors to inform how historical structural racism could be associated with beneficial cancer outcomes among privileged racial and ethnic groups.

JAMA Network Open. 2022;5(7):e2220908. doi:10.1001/jamanetworkopen.2022.20908

Introduction

Historical and current structural racism are conceptualized as main drivers of cancer disparities by race and ethnicity,¹⁻³ including poorer breast cancer outcomes experienced by US women self-identifying as Black or African American.⁴ Race-based policies and practices of exclusion such as Jim Crow laws in the South, housing covenants barring residents of color, and mortgage lending based on the percentage of residents from minoritized racial and ethnic groups in an area (ie, redlining) have contributed to poorer social and economic well-being among African Americans and minoritized racial and ethnic groups.⁵⁻⁹ Moreover, enduring place-based characteristics and policies (eg, locations of highways and other built environment factors; zoning codes; school district boundaries; municipal tax rates, revenues, and expenditures),¹⁰⁻¹⁴ as well as intergenerational transmission of socioeconomic factors, can indirectly translate decades-old structural racism into adverse health outcomes for people from minoritized racial and ethnic groups alive today who were not necessarily directly impacted by racist policies and practices that have since been abolished.¹⁵⁻¹⁷

There is a complex interplay among contemporary racial and ethnic stratification within residential areas,¹⁸⁻²⁰ inequities in health care and built environment access,²¹⁻²⁵ socioeconomic status,²⁶⁻²⁸ wealth,²⁶ and health behaviors.²⁹⁻³¹ These current factors may also be connected to historical processes involving mortgage lending discrimination.^{7,31,32} The now well-known 1930s Home Owners' Loan Corporation (HOLC) mortgage security redlining maps of major metropolitan housing markets were originally created to assess lending risk across US cities and improve profitability of loans.³³⁻³⁵ Assessors assigned 1 of 4 grades: "best," "still desirable," "definitely declining," or "hazardous" to neighborhoods partially based on the presence of "foreign-born" and "negro" residents.³⁵ Analysis of the HOLC grading sheets indicates that historical presence of residents from minoritized racial and ethnic groups, poorer housing quality, average housing price, and older housing stock correlate with worse grading.³⁵ Regardless of the debate over whether HOLC maps were subsequently used for mortgage lending decisions,^{34,35} there is general consensus that the racially prejudiced beliefs that motivated the HOLC maps also reinforced racial and ethnic stratification.

A small body of literature has begun to investigate associations between measures of mortgage lending discrimination by race and breast cancer outcomes.³⁶⁻³⁹ A study of breast cancer mortality within a Surveillance, Epidemiology, and End Results (SEER)-Medicare linkage found that greater likelihood of present-day redlining was associated with greater hazard of death among breast cancer cases.³⁸ This association did not vary by race and ethnicity. Redlining values reflected mortgage applicants' relative likelihood of loan denial within their residential census tract compared with denials outside their census tract.⁴⁰ A study within the Metropolitan area of Atlanta, Georgia, found that greater redlining was associated with higher breast cancer-specific mortality among all women, with a potentially blunted association among non-Hispanic Black women.³⁷ Another study investigated associations between HOLC, historical redlining, and breast cancer stage within areas of Massachusetts. Among 20 808 women diagnosed between 2001 and 2015, higher odds of late-stage disease was associated with residence in census tracts historically redlined compared with census tracts considered the lowest historical mortgage lending risk.³⁶ This association was adjusted for race and ethnicity and most pronounced in census tracts characterized as economically and racially privileged (ie, high proportion of high-income and non-Latina White households), according to 2000 to 2017 census and American Community Survey data. A similarly framed Massachusetts-based study of incident breast cancer hormone receptor status found that the association between

incidence of estrogen and progesterone negative tumors and residence in census tracts with historical redlining was dependent on current census tract economic and racial privilege³⁹; albeit with highly mixed findings.

The racially directed nature of lending discrimination and evidence for racial and ethnic interactions from previous studies underscore the importance of analyses that test for variation in effect estimates by race and ethnicity. Moreover, to our knowledge, there is no literature reporting on associations between redlining and breast tumor grade or triple-negative breast cancer (TNBC)—both clinically relevant outcomes potentially influenced by social factors and which exhibit variation by race and ethnicity.^{41,42} Stress and inflammatory pathways have been proposed as possible biologic mediators between racism and health outcomes, including breast cancer outcomes, and potential contributors to racial and ethnic disparities.^{1,43-45} Accordingly, this study investigates associations between 1930s-era HOLC redlining, racial and ethnic identity, and breast cancer stage, grade, TNBC, and mortality among women diagnosed between 2008 and 2017 while a resident of a metropolitan area of New Jersey.

Methods

Study Design

This cohort study was conducted using a population-based cancer registry in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cohort studies.⁴⁶ The institutional review board of Rutgers University approved this study and informed consent was waived as data were from the state registry.

Data Sources

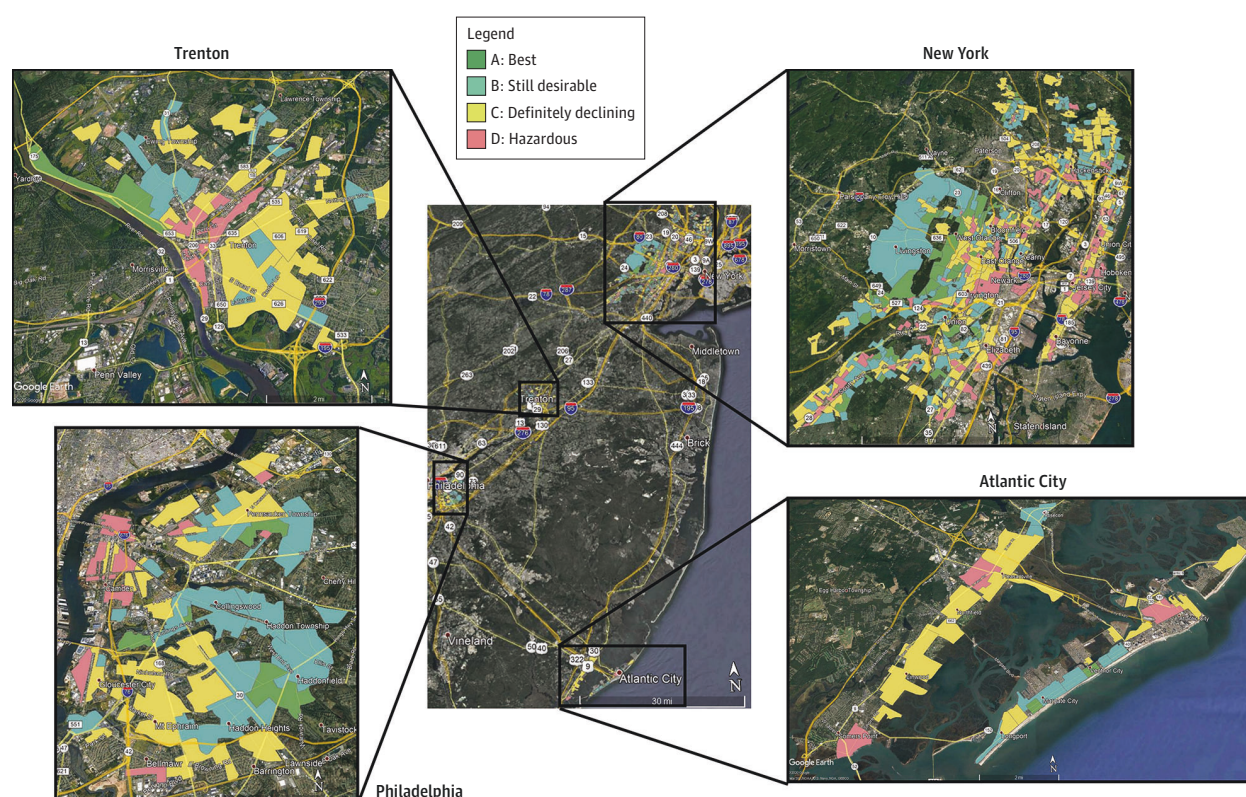
Historical, georeferenced HOLC grading data were retrieved from the University of Richmond's Digital Scholarship Lab.⁴⁷ Assessments were dated between March 1937 and April 1940 and available within portions of 4 New Jersey counties (Bergen, Essex, Hudson, and Union) and 2 municipalities (Atlantic City and Trenton). Risk grades of A, B, C, and D corresponded to "best" (first grade), "still desirable" (second grade), "definitely declining" (third grade), and "hazardous" (fourth grade) within assessment sheets and color shading of green, blue, yellow, and red, respectively, in maps (**Figure**). An HOLC grade was attributed to each patient with breast cancer whose geocoded residential address at diagnosis fell within a historical HOLC area.

Cancer data were abstracted from the New Jersey State Cancer Registry (NJSCR) for all female residents of a HOLC-graded area, aged at least 20 years, diagnosed with a primary, histologically confirmed, invasive breast cancer between 2008 and 2017 (n = 15 025). Sociodemographic (age at diagnosis, race, ethnicity, geocoded residential address, date of diagnosis), tumor (stage at diagnosis, grade, subtype), and vital status (cause and date of death) data were also from the NJSCR. Age was collapsed into 5 categories: less than 40 years, 40 to 49 years, 50 to 64 years, 65 to 74 years, and at least 75 years. Race and ethnicity—primarily reported by health care facilities such as hospitals, physician offices, and other outpatient clinics like outpatient surgical centers (see eMethods in the [Supplement](#) for details)—were combined into Latina, non-Latina White, non-Latina Black, and other (non-Latina Asian/Pacific Islander/Native American/Alaska Native/Hawaiian and not otherwise specified). Stage at diagnosis was from SEER collaborative stage 2000, and any missing or unknown values were set to values from SEER summary stage 2000. Stage was dichotomized into early (localized and regional) and late (distant). Tumor grade was dichotomized into low (well and moderately well differentiated) and high (poorly differentiated and undifferentiated). Subtype was collapsed into TNBC (ie, negative for each of estrogen receptor, progesterone receptor), and human epidermal growth factor receptor 2) vs non-TNBC. Breast cancer-specific death was based on *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* (ICD-10) codes C50 to C50.9.

Statistical Analysis

Race and ethnicity data were missing for 61 cases (0.4%), which were excluded from the analysis. Unknown and missing values for tumor subtype (1894 [12.7%]), grade (1620 [10.8%]), and stage (440 [2.9%]) were imputed using fully conditional specification multiple imputation resulting in 25 imputed data sets each with 14 964 cases.⁴⁸ Cases missing follow-up time (151 [1.0%]) were included in multiple imputation analyses to maximize the number of non-survival outcomes but excluded from survival analyses. Sociodemographic and tumor factors were summarized by HOLC grades. Logistic regression models of tumor factors (TNBC, grade, stage) and Cox proportional hazard models of breast cancer–specific death were created, respectively, to investigate associations between outcomes, HOLC grade, and race and ethnicity while adjusting for age and year of diagnosis. Multiplicative interactions between HOLC grade and race and ethnicity were tested in each model of breast cancer outcomes. A random intercept for HOLC area was included in each model to account for clustered outcomes by HOLC area.⁴⁹ Cases not experiencing breast cancer–specific mortality were right censored at the date of mortality from other causes or until end of follow-up, December 31, 2019. We calculated effect estimates (odds ratios [OR] from logistic models and hazard ratios [HR] from Cox models) and 95% CIs from each of the 3 tumor factor models and survival model. The proportional hazards assumption of Cox models was investigated through Schoenfeld residual plots, which indicated no violations. Multiple imputation results were combined and reported by the Rubin rule.⁴⁸ As a sensitivity test of unstable estimates due to small frequencies, we collapsed grades A and B into 1 category and C and D into another category and repeated models. As post hoc analyses: (1) we calculated *F*-tests (logistic models) and χ^2 tests (Cox model) to test whether estimated outcomes varied across HOLC grades, by racial and ethnic groups (see eResults in the [Supplement](#)), and (2) report observed and imputed sample size by HOLC grade and breast cancer outcomes (see eTable 1 and eTable 2 in the [Supplement](#)). We assessed statistical significance by magnitude of effect estimates (OR and HR) and statistical precision of effect estimates (95% CI). Analyses were

Figure. Historical Home Owner's Loan Corporation Redlining Grades, 1937-1940, New Jersey



conducted between June and December 2021 using ArcGIS version 10.6 (Esri) and SAS version 9.4 (SAS Institute).

Results

Within each New Jersey metropolitan area with historical HOLC redlining grades available, worse HOLC grade areas were concentrated toward the urban cores as evident in Trenton, Camden, Atlantic City, and numerous populous cities in the Northeastern portion of the State (Newark, Elizabeth, Jersey City, Hoboken, Union City) (Figure).

There was a total of 14 964 women with breast cancer. Of these, 2689 were Latina, 3506 were non-Latina Black, 7686 were non-Latina White, and 1083 were other races and ethnicities (non-Latina Asian/Pacific Islander/Native American/Alaska Native/Hawaiian or not otherwise specified). Distributions of sociodemographic and tumor factors by residence within historical HOLC grades are shown in **Table 1**. Approximately 25% of non-Latina Black (26.1% [914 of 3506]) and Latina (27.7% [746 of 2689]) patients resided in “hazardous” HOLC grades compared with 12.5% of non-Latina White patients (964 of 7686); 69.4% of patients with late-stage diagnosis (761 of 1097) resided in the “definitely declining” or “hazardous” HOLC grades compared with 64.2% of patients with early

Table 1. Distributions of Sociodemographic and Breast Tumor Factors by Historical HOLC Grade, New Jersey, 2008-2017 (N = 14 964)

Characteristic	Frequency and percentage of cases				
	Total	HOLC grade			
		“Best”	“Still desirable”	“Definitely declining”	“Hazardous”
Overall		1155 (7.7)	4131 (27.6)	6842 (45.7)	2836 (18.9)
Race and ethnicity					
Latina	2689 (18.0)	75 (2.8)	415 (15.4)	1453 (54.0)	746 (27.7)
Non-Latina					
Black	3506 (23.4)	217 (6.2)	768 (21.9)	1607 (45.8)	914 (26.1)
White	7686 (51.4)	809 (10.5)	2700 (35.1)	3213 (41.8)	964 (12.5)
Other ^a	1083 (7.2)	54 (5.0)	248 (22.9)	569 (52.5)	212 (19.6)
Age, y					
<40	899 (6.0)	51 (5.7)	200 (22.2)	427 (47.5)	221 (24.6)
40-49	2930 (19.6)	249 (8.5)	799 (27.3)	1351 (46.1)	531 (18.1)
50-64	5622 (37.6)	446 (7.9)	1564 (27.8)	2569 (45.7)	1043 (18.6)
65-74	2986 (20.0)	223 (7.5)	843 (28.2)	1348 (45.1)	572 (19.2)
≥75	2527 (16.9)	186 (7.4)	725 (28.7)	1147 (45.4)	469 (18.6)
Year of diagnosis					
2008-2011	5600 (37.4)	438 (7.8)	1519 (27.1)	2585 (46.2)	1058 (18.9)
2012-2014	4509 (30.1)	349 (7.7)	1303 (28.9)	2052 (45.5)	805 (17.9)
2015-2017	4855 (32.4)	368 (7.6)	1309 (27.0)	2205 (45.4)	973 (20.0)
Stage					
Early	13427 (89.7)	1070 (8.0)	3742 (27.9)	6137 (45.7)	2478 (18.5)
Late	1097 (7.3)	57 (5.2)	279 (25.4)	514 (46.9)	247 (22.5)
Missing	440 (2.9)	28 (6.4)	110 (25.0)	191 (43.4)	111 (25.2)
Grade					
Low	8125 (54.3)	715 (8.8)	2377 (29.3)	3547 (43.7)	1486 (18.3)
High	5219 (34.9)	334 (6.4)	1338 (25.6)	2522 (48.3)	1025 (19.6)
Missing	1620 (10.8)	106 (6.5)	416 (25.7)	773 (47.7)	325 (20.1)
Subtype					
Not triple-negative	11 467 (76.6)	946 (8.2)	3268 (28.5)	5213 (45.5)	2040 (17.8)
Triple-negative	1603 (10.7)	100 (6.2)	401 (25.0)	757 (47.2)	345 (21.5)
Missing	1894 (12.7)	109 (5.8)	462 (24.4)	872 (46.0)	451 (23.8)

Abbreviation: HOLC, Home Owners' Loan Corporation.

^a Other race and ethnicity included Asian/Pacific Islander/Native American/Alaska Native/Hawaiian and not otherwise specified.

stage (8615 of 13427) who resided in the “definitely declining” or “hazardous” HOLC grades; 67.9% of patients with high tumor grades (3547 of 5219) resided in the “definitely declining” or “hazardous” HOLC grades compared with 62.0% of cases with low tumor grades (5033 of 8125) who resided in the “definitely declining” or “hazardous” HOLC grades; 68.7% of cases with TNBC (1102 of 1603) resided in the “definitely declining” or “hazardous” HOLC grades compared with 63.3% of cases (7253 of 11467) without TNBC who resided in the “definitely declining” or “hazardous” HOLC grades.

Median follow-up time was 5.3 years (95% CI, 5.2-5.3). With 1755 breast cancer-specific deaths the estimated 5-year breast cancer-specific survival was 88.0% (95% CI, 87.4%-88.6%). Estimated associations between HOLC grade and each outcome varied by race and ethnicity (**Table 2**). The race and ethnicity-dependent associations varied in a similar pattern across all 4 breast cancer outcomes; compared with residence in HOLC areas graded as “hazardous,” residence in historical HOLC areas graded “best” was associated with lower odds of late-stage diagnosis (odds ratio [OR], 0.34 [95% CI, 0.22-0.53]), lower odds of high tumor grade (OR, 0.72 [95% CI, 0.57-0.91]), lower odds of TNBC (OR, 0.67 [95% CI, 0.47-0.95]), and lower hazard of breast cancer-specific death (hazard ratio, 0.48 [95% CI, 0.35-0.65]) but only among non-Latina White women. Among non-Latina White women, residence in “still desirable” compared with “hazardous” or “definitely declining” compared with “hazardous” was also associated with lower odds of late-stage disease and lower hazard of breast cancer-specific death. The only other evidence of race and ethnicity-specific associations was among women from the other race and ethnicity category, which showed that compared with those residing

Table 2. Associations Between Late Stage, High Grade, TNBC, and Breast Cancer-Specific Death by Historical HOLC Grade and Sociodemographic Variables, New Jersey, 2008-2017

	OR (95% CI)			Breast cancer specific-death, HR (95% CI) ^d
Factors	Late stage ^a	High grade ^b	TNBC ^c	
HOLC “best” vs “hazardous”				
Non-Latina				
White	0.34 (0.22-0.53)	0.72 (0.57-0.91)	0.67 (0.47-0.95)	0.48 (0.35-0.65)
Black	1.02 (0.59-1.75)	1.01 (0.73-1.41)	1.06 (0.70-1.60)	0.78 (0.53-1.15)
Other ^e	0.81 (0.22-2.98)	0.84 (0.44-1.61)	0.78 (0.25-2.44)	1.07 (0.30-3.84)
Latina	0.72 (0.25-2.07)	0.71 (0.42-1.21)	0.49 (0.19-1.29)	0.88 (0.41-1.92)
HOLC “still desirable” vs “hazardous”				
Non-Latina				
White	0.65 (0.50-0.86)	0.94 (0.79-1.12)	0.82 (0.63-1.06)	0.60 (0.48-0.74)
Black	1.00 (0.69-1.43)	0.93 (0.74-1.16)	1.00 (0.76-1.30)	0.86 (0.67-1.10)
Other ^e	0.36 (0.14-0.96)	0.94 (0.63-1.42)	0.90 (0.46-1.76)	1.47 (0.70-3.10)
Latina	0.73 (0.43-1.24)	0.94 (0.72-1.21)	0.72 (0.48-1.08)	0.90 (0.61-1.33)
HOLC “definitely declining” vs “hazardous”				
Non-Latina				
White	0.72 (0.55-0.93)	1.15 (0.96-1.37)	0.93 (0.73-1.19)	0.74 (0.60-0.90)
Black	1.03 (0.75-1.40)	0.98 (0.80-1.19)	1.00 (0.79-1.27)	1.04 (0.85-1.27)
Other ^e	0.82 (0.43-1.59)	0.93 (0.65-1.32)	0.85 (0.47-1.52)	1.14 (0.58-2.26)
Latina	0.83 (0.57-1.20)	1.01 (0.83-1.23)	0.91 (0.69-1.20)	0.94 (0.71-1.25)
Age, y				
<40	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
40-49	0.56 (0.42-0.74)	0.58 (0.50-0.68)	0.75 (0.61-0.93)	0.61 (0.49-0.74)
50-64	0.83 (0.64-1.07)	0.53 (0.46-0.62)	0.70 (0.57-0.86)	0.72 (0.60-0.87)
65-74	0.73 (0.56-0.96)	0.38 (0.33-0.45)	0.61 (0.49-0.76)	0.77 (0.63-0.94)
≥75	1.11 (0.85-1.45)	0.37 (0.31-0.43)	0.56 (0.44-0.70)	1.42 (1.17-1.72)
Year of diagnosis				
2015-2017	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
2012-2014	0.92 (0.78-1.08)	1.20 (1.10-1.31)	1.06 (0.93-1.21)	0.92 (0.78-1.08)
2008-2011	0.97 (0.84-1.13)	1.23 (1.13-1.35)	1.26 (1.11-1.42)	0.97 (0.84-1.13)

Abbreviations: HR, hazard ratio; HOLC, Home Owners' Loan Corporation; OR, odds ratio; TNBC, triple-negative breast cancer.

^a From logistic regression models of the probability of late stage (vs early) at diagnosis adjusted for all covariates listed, a random intercept for HOLC area, and accounting for multiple imputation variability.

^b From logistic regression models of the probability of high-grade tumor (vs low-grade) adjusted for all covariates listed, a random intercept for HOLC area, and accounting for multiple imputation variability.

^c From logistic regression models of the probability of triple-negative breast cancer (vs non-TNBC) adjusted for all covariates listed, a random intercept for HOLC area, and accounting for multiple imputation variability.

^d From a Cox proportional hazard model of breast cancer-specific death adjusted for all covariates listed and a random intercept for HOLC area, and accounting for multiple imputation variability.

^e Other race and ethnicity included Asian/Pacific Islander/Native American/Alaska Native/Hawaiian and not otherwise specified.

in HOLC areas graded “hazardous,” residence in HOLC areas graded “still desirable” was associated with lower odds of late-stage diagnosis. Women with breast cancer who were at least 40 years of age had lower odds of late stage, high grade, and TNBC and lower hazard of breast cancer–specific death compared with those younger than 40 years (except for those at least 75 years of age in the late stage and survival models). Diagnosis in earlier years (2008 to 2011) was associated with higher odds of high grade and TNBC compared with more recent diagnosis. Results from models using HOLC grade collapsed into “best”/“still desirable” and “definitely declining”/“hazardous” were qualitatively similar. Results of post hoc analyses that formally test variation in estimated odds or hazard across HOLC grades by race and ethnicity support our results interpretation of Table 2 (eResults in the [Supplement](#)).

Discussion

We tested whether current-day residence in historically demarcated areas that indicated mortgage lending discrimination by race and ethnicity (ie, redlining) was associated with recent breast cancer outcomes, and whether associations varied by race and ethnicity. Compared with residence in previously redlined areas, residence in non-redlined areas was associated with more favorable breast cancer outcomes—lower odds of late stage at diagnosis, high tumor grade, TNBC subtype, and lower hazards of breast cancer–specific death—almost exclusively among non-Latina White women. Most associations between redlining measures and breast cancer outcomes among breast cancer cases of other racial and ethnic groups had small effect estimates and wide confidence intervals, except for the lower odds of late stage comparing residence in areas deemed “still desirable” to redlined areas among women who were non-Latina Asian/Pacific Islander/Native American/Alaska Native/Hawaiian or not otherwise specified.

Other studies of HOLC redlining and breast cancer outcomes linked residential census tract at diagnosis to Massachusetts HOLC data and a Census Bureau–based measure of racialized economic segregation to investigate associations with late-stage and incident breast cancer by hormone receptor status.^{36,39} In the study of incident breast cancer by hormone receptor type, incidence of breast cancer was higher in non-redlined areas compared with redlined areas with the largest differences among census tracts considered to have the least present-day privilege—a result that was consistent across estrogen and progesterone receptor positive and negative tumors.³⁹ In the study of late-stage breast cancer, there was evidence of an interaction involving racialized economic privilege such that proportion of late-stage diagnoses were lower in non-redlined areas compared with redlined areas most consistently among census tracts considered to have present-day socioeconomic privilege. A study of contemporary mortgage lending discrimination by race and ethnicity and breast cancer–specific death similarly found that residence in redlined areas was associated with a higher hazard of death only among non-Hispanic White patients with breast cancer.³⁷

The few extant cancer epidemiology studies of residential redlining typically frame the role of racial discrimination as a health-adverse effect experienced by individuals identifying as a member of a minoritized racial or ethnic group, and who were targets of harmful practices and policies.^{36,37} Implied, but less discussed, is the potential for racial and ethnic disparities in cancer to persist due to historical efforts to preserve perceived benefits (ie, privilege) within neighborhoods that were overwhelmingly comprised of people identifying as White.³⁵ This reorientation prompts consideration of how neighborhoods of mostly White people might have benefited in addition to or regardless of any harmful discriminatory effects experienced by individuals of a minoritized racial or ethnic group residing in redlined areas. This slight shift in perspective also allows for a common explanation of cancer inequities resulting from historical redlining, racialized housing covenants, and Jim Crow laws that have been legally abolished for decades—although with long-lasting impacts—as well as current, legal municipal zoning policies, public housing voucher allocations, and public school boundary delineations: each effectively maintaining perceived or actual advantages among already advantaged racial and ethnic groups.¹⁰⁻¹⁴

Thus, current-day residence in non-redlined areas might reflect historical access to better resources (eg, education, income, employment, wealth) that ultimately lead to more favorable breast cancer outcomes only among White populations. This might be due to intergenerational transmission of wealth and socioeconomic status not afforded to individuals residing in areas that were redlined or deemed less desirable for mortgage lending purposes. Relationships with additional factors that correlate with approximated HOLC boundaries, such as average levels of interpersonal discrimination should also be considered as previous research shows that residents who are among the numerical minority and self-identity as part of a minoritized racial or ethnic group report greater interpersonal discrimination as the proportion of their neighbors who identify as White increases.^{50,51} If this finding applied to the current study and non-redlined areas have higher proportions of White residents, then the breast cancer–beneficial mechanisms experienced by individuals from minoritized racial and ethnic groups residing in non-redlined areas could be offset by greater interpersonal discrimination ultimately leading to null associations between redlining and breast cancer outcomes for these residents who identify as part of minoritized racial and ethnic groups.

Potential biologic mechanisms underpinning relationships involving breast cancer outcomes, self-identified race and ethnicity, and interpersonal and structural racism could involve chronic psychosocial stress and genomic markers of inflammation (eg, DNA methylation or gene expression of interleukin receptors, C-reactive protein).^{43–45} Empirical studies designed explicitly to test whether stress and genomic inflammatory markers mediate associations between racism and breast cancer are lacking. However, one study has reported differential breast tumor methylation of numerous genes by neighborhood socioeconomic factors, with at least 1 such gene also correlating with mortality following a breast cancer diagnosis.⁵² Future studies of HOLC residence and cancer outcomes should strive to collect such additional measures as interpersonal discrimination, individual socioeconomic status, stress, and markers of inflammation to test these hypotheses.

Study Limitations

In addition to unmeasured covariates for testing mechanistic pathways, this study is limited by the potential for HOLC exposure misclassification, geographic scope, and moderate sample size within specific strata. Although totaling nearly 15 000 total breast cancer cases, relatively few Latina women or women from other racial and ethnic groups resided in historical HOLC areas deemed “best,” which could have reduced the power to test associations. Factors specific to New Jersey—such as population migration and mobility, population density, racial and ethnic residential segregation—prevent generalization of these results to other areas. Exposure misclassification due to residential mobility patterns limit more complete characterization of the potential role of HOLC in breast cancer outcomes. Given the aforementioned potential mechanisms, it is expected that duration of residence would influence associations. Strengths include availability of data from a high-quality populous state cancer registry, linkage to the HOLC data set using geocoded residential addresses (as opposed to census tracts) to minimize geographic measurement error, and use of multilevel models and multiple imputation for improved accuracy of effect estimates.

Conclusions

Historical redlining is one of many examples of structural racism that were ultimately motivated by the desire to maintain perceived advantages among people identifying as White. Although some portion of health inequities may be due to adverse effects experienced by targets of discrimination, racial and ethnic disparities in breast cancer prognostic factors and survival may also result from such practices and policies as historical redlining that disproportionately benefited White communities. This study highlights the importance of historical, race-based, conceptual framing of breast cancer disparities, and the importance of high-quality data that can be used to investigate such conceptualized relationships. Future studies should seek to replicate these findings in other US states and with estimates of exposure duration based on residential history data.

ARTICLE INFORMATION

Accepted for Publication: May 20, 2022.

Published: July 8, 2022. doi:10.1001/jamanetworkopen.2022.20908

Open Access: This is an open access article distributed under the terms of the [CC-BY License](#). © 2022 Plascak JJ et al. JAMA Network Open.

Corresponding Author: Jesse J. Plascak, PhD, College of Medicine, Division of Cancer Prevention and Control, Department of Internal Medicine, The Ohio State University, 1590 N High St, Ste 525, Columbus, OH 43201 (jesse.plascak@osumc.edu).

Author Affiliations: Comprehensive Cancer Center, The Ohio State University, Columbus (Plascak); Division of Cancer Prevention and Control, Department of Internal Medicine, College of Medicine, The Ohio State University, Columbus (Plascak); Institute for Health and Society, Division of Epidemiology, Medical College of Wisconsin, Milwaukee (Beyer); Department of Statistics, The Ohio State University, Columbus (Xu); Department of Biostatistics and Epidemiology, Rutgers School of Public Health, Piscataway, New Jersey (Stroup, Jacob); Rutgers Cancer Institute of New Jersey, New Brunswick (Stroup); New Jersey State Cancer Registry, New Jersey Department of Health, Trenton (Stroup); Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, New York (Llanos); Herbert Irving Comprehensive Cancer Center, Columbia University Irving Medical Center, New York, New York (Llanos).

Author Contributions: Prof Plascak had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Plascak, Beyer.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Plascak.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Plascak, Xu.

Obtained funding: Plascak, Llanos.

Administrative, technical, or material support: Beyer, Stroup, Llanos.

Supervision: Plascak.

Conflict of Interest Disclosures: None reported.

Funding/Support: This study was supported by funds from the Cancer Institute of New Jersey (P30CA072720-19: Cancer Prevention and Control Pilot award to Dr Plascak; New Investigator Award to Dr Llanos) and the National Cancer Institute (R01CA214805 to KB). Data provided by New Jersey State Cancer Registry through funding from the Surveillance, Epidemiology and End Results (SEER) Program of the National Cancer Institute (HHSN261201300021I), the National Program of Cancer Registries (NPCR), Centers for Disease Control and Prevention (5U58DP003931-02), the State of New Jersey, and the Rutgers Cancer Institute of New Jersey.

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

REFERENCES

1. Williams DR, Mohammed SA, Shields AE. Understanding and effectively addressing breast cancer in African American women: unpacking the social context. *Cancer*. 2016;122(14):2138-2149. doi:10.1002/cncr.29935
2. Krieger N. Theoretical frameworks and cancer inequities. In: Vaccarella S, Saracci R, Lortet-Tieulent J, Straif K, Conway DI, Wild CP, eds. *Reducing social inequalities in cancer: evidence and priorities for research*. WHO Press; 2019:189.
3. McCullough LE. The long red line: breast cancer incidence at the intersection of unjust structural policies and their contemporary manifestations. *JNCI Cancer Spectr*. 2022;6(2):pkac018. doi:10.1093/jncics/pkac018
4. Islami F, Guerra CE, Minihan A, et al. American Cancer Society's report on the status of cancer disparities in the United States, 2021. *CA Cancer J Clin*. 2022;72(2):112-143. doi:10.3322/caac.21703
5. Krieger N, Chen JT, Coull B, Waterman PD, Beckfield J. The unique impact of abolition of Jim Crow laws on reducing inequities in infant death rates and implications for choice of comparison groups in analyzing societal determinants of health. *Am J Public Health*. 2013;103(12):2234-2244. doi:10.2105/AJPH.2013.301350
6. Aalbers MB. How do mortgage lenders influence neighbourhood dynamics? redlining and predatory lending. In: van Ham M, Manley D, Bailey N, Simpson L, Maclennan D, eds. *Understanding Neighbourhood Dynamics*. Springer; 2013:63-85.

7. Massey DS, Rugh JS, Steil JP, Albright L. Riding the stagecoach to hell: a qualitative analysis of racial discrimination in mortgage lending. *City Community*. 2016;15(2):118-136. doi:10.1111/cico.12179
8. Silva C. Racial restrictive covenants: enforcing neighborhood segregation in Seattle. The Seattle Civil Rights and Labor History Project. Accessed June 10, 2022. https://depts.washington.edu/civilr/covenants_report.htm
9. Martin CA, Peterson KA, Stabler LB. Residential landscaping in Phoenix, Arizona, US: practices and preferences relative to covenants, codes, and restrictions. *J Arboric*. 2003;29(1):9-17.
10. Saporito S, Sohoni D. Coloring outside the lines: racial segregation in public schools and their attendance boundaries. *Sociol Educ*. 2006;79(2):81-105. doi:10.1177/003804070607900201
11. Roberts A, Lakes RD. Middle-class mothers on urban school selection in gentrifying areas. *Educ Urban Soc*. 2016;48(3):203-220. doi:10.1177/0013124514530152
12. Dannenberg AL, Jackson RJ, Frumkin H, et al. The impact of community design and land-use choices on public health: a scientific research agenda. *Am J Public Health*. 2003;93(9):1500-1508. doi:10.2105/AJPH.93.9.1500
13. Li XJ, et al. Who lives in greener neighborhoods? The distribution of street greenery and its association with residents' socioeconomic conditions in Hartford, Connecticut, USA. *Urban For Urban Green*. 2015;14(4):751-759. doi:10.1016/j.ufug.2015.07.006
14. Fulton JE, Carlson SA, Ainsworth BE, et al. Strategic Priorities for Physical Activity Surveillance in the United States. Strategic priorities for physical activity surveillance in the United States. *Med Sci Sports Exerc*. 2016;48(10):2057-2069. doi:10.1249/MSS.0000000000000989
15. Rothwell J, Massey DS. Geographic effects on intergenerational income mobility. *Econ Geogr*. 2015;91(1):83-106. doi:10.1111/ecge.12072
16. Chetty R, Hendren N. The impacts of neighborhoods on intergenerational mobility I: childhood exposure effects. *Q J Econ*. 2018;133(3):1107-1162. doi:10.1093/qje/qjy007
17. Chetty R, et al. Race and economic opportunity in the United States: an intergenerational perspective. *Q J Econ*. 2020;135(2):711-783. doi:10.1093/qje/qjz042
18. Massey DS, Tannen J. A research note on trends in Black hypersegregation. *Demography*. 2015;52(3):1025-1034. doi:10.1007/s13524-015-0381-6
19. Logan JR. The persistence of segregation in the 21st century metropolis. *City & Community*. 2013;12(2):160-168. doi:10.1111/cico.12021
20. Reardon SF, Matthews SA, O'Sullivan D, et al. The geographic scale of metropolitan racial segregation. *Demography*. 2008;45(3):489-514. doi:10.1353/dem.0.0019
21. Dinwiddie GY, Gaskin DJ, Chan KS, Norrington J, McCleary R. Residential segregation, geographic proximity and type of services used: evidence for racial/ethnic disparities in mental health. *Soc Sci Med*. 2013;80:67-75. doi:10.1016/j.socscimed.2012.11.024
22. Gaskin DJ, Dinwiddie GY, Chan KS, McCleary R. Residential segregation and disparities in health care services utilization. *Med Care Res Rev*. 2012;69(2):158-175. doi:10.1177/1077558711420263
23. Dai D. Black residential segregation, disparities in spatial access to health care facilities, and late-stage breast cancer diagnosis in metropolitan Detroit. *Health Place*. 2010;16(5):1038-1052. doi:10.1016/j.healthplace.2010.06.012
24. Haas JS, Earle CC, Orav JE, et al. Racial segregation and disparities in breast cancer care and mortality. *Cancer*. 2008;113(8):2166-2172. doi:10.1002/cncr.23828
25. Plascak JJ, Schootman M, Rundle AG, et al. Spatial predictive properties of built environment characteristics assessed by drop-and-spin virtual neighborhood auditing. *Int J Health Geogr*. 2020;19(1):21. doi:10.1186/s12942-020-00213-5
26. Bailey ZD, Krieger N, Agénor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. *Lancet*. 2017;389(10077):1453-1463. doi:10.1016/S0140-6736(17)30569-X
27. Colen CG, Ramey DM, Cooksey EC, Williams DR. Racial disparities in health among nonpoor African Americans and Hispanics: the role of acute and chronic discrimination. *Soc Sci Med*. 2018;199:167-180. doi:10.1016/j.socscimed.2017.04.051
28. Braveman PA, Cubbin C, Egerter S, Williams DR, Pamuk E. Socioeconomic disparities in health in the United States: what the patterns tell us. *Am J Public Health*. 2010;100(S1)(suppl 1):S186-S196. doi:10.2105/AJPH.2009.166082
29. August KJ, Sorkin DH. Racial/ethnic disparities in exercise and dietary behaviors of middle-aged and older adults. *J Gen Intern Med*. 2011;26(3):245-250. doi:10.1007/s11606-010-1514-7

30. Borrell LN, Kiefe CI, Diez-Roux AV, Williams DR, Gordon-Larsen P. Racial discrimination, racial/ethnic segregation, and health behaviors in the CARDIA study. *Ethn Health*. 2013;18(3):227-243. doi:10.1080/13557858.2012.713092
31. Williams DR, Lawrence JA, Davis BA, Vu C. Understanding how discrimination can affect health. *Health Serv Res*. 2019;54(suppl 2):1374-1388. doi:10.1111/1475-6773.13222
32. White K, Borrell LN. Racial/ethnic residential segregation: framing the context of health risk and health disparities. *Health Place*. 2011;17(2):438-448. doi:10.1016/j.healthplace.2010.12.002
33. Michney TM, Winling L. New perspectives on New Deal housing policy: explicating and mapping HOLC loans to African Americans. *J Urban Hist*. 2020;46(1):150-180. doi:10.1177/0096144218819429
34. Hillier AE. Redlining and the Home Owners' Loan Corporation. *J Urban Hist*. 2003;29(4):394-420. doi:10.1177/0096144203029004002
35. Greer J. The Home Owners' Loan Corporation and the development of the residential security maps. *J Urban Hist*. 2013;39(2):275-296. doi:10.1177/0096144212436724
36. Krieger N, Wright E, Chen JT, Waterman PD, Huntley ER, Arcaya M. Cancer stage at diagnosis, historical redlining, and current neighborhood characteristics: breast, cervical, lung, and colorectal cancers, Massachusetts, 2001-2015. *Am J Epidemiol*. 2020;189(10):1065-1075. doi:10.1093/aje/kwaa045
37. Collin LJ, et al. Neighborhood-level redlining and lending bias are associated with breast cancer mortality in a large and diverse metropolitan area. *Cancer Epidemiol Biomarkers Prev*. 2021;30(1):53-60.
38. Beyer KMM, Zhou Y, Laud PW, et al. Mortgage lending bias and breast cancer survival among older women in the United States. *J Clin Oncol*. 2021;39(25):2749-2757. doi:10.1200/JCO.21.00112
39. Wright E, Waterman PD, Testa C, Chen JT, Krieger N. Breast cancer incidence, hormone receptor status, historical redlining, and current neighborhood characteristics in Massachusetts, 2005-2015. *JNCI Cancer Spectr*. 2022;6(2):pkac016. doi:10.1093/jncics/pkac016
40. Beyer KMM, Zhou Y, Matthews K, Bemanian A, Laud PW, Nattinger AB. New spatially continuous indices of redlining and racial bias in mortgage lending: links to survival after breast cancer diagnosis and implications for health disparities research. *Health Place*. 2016;40:34-43. doi:10.1016/j.healthplace.2016.04.014
41. Krieger N, Jahn JL, Waterman PD. Jim Crow and estrogen-receptor-negative breast cancer: US-born Black and White non-Hispanic women, 1992-2012. *Cancer Causes Control*. 2017;28(1):49-59. doi:10.1007/s10552-016-0834-2
42. Kong X, Liu Z, Cheng R, et al. Variation in breast cancer subtype incidence and distribution by race/ethnicity in the United States from 2010 to 2015. *JAMA Netw Open*. 2020;3(10):e2020303. doi:10.1001/jamanetworkopen.2020.20303
43. Carlos RC, Obeng-Gyasi S, Cole SW, et al. Linking structural racism and discrimination and breast cancer outcomes: a social genomics approach. *J Clin Oncol*. 2022;40(13):1407-1413. doi:10.1200/JCO.21.02004
44. Saini G, Ogden A, McCullough LE, Torres M, Rida P, Aneja R. Disadvantaged neighborhoods and racial disparity in breast cancer outcomes: the biological link. *Cancer Causes Control*. 2019;30(7):677-686. doi:10.1007/s10552-019-01180-4
45. Cuevas AG, Ong AD, Carvalho K, et al. Discrimination and systemic inflammation: a critical review and synthesis. *Brain Behav Immun*. 2020;89:465-479. doi:10.1016/j.bbi.2020.07.017
46. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Epidemiology*. 2007;18(6):800-804. doi:10.1097/EDE.0b013e3181577654
47. Nelson RK, et al. Mapping inequality: Redlining in new deal America. American Panorama 2018. Accessed October 30, 2020. <https://dsl.richmond.edu/panorama/redlining/>
48. Rubin DB. *Multiple imputation for nonresponse in surveys*. Vol 81. John Wiley & Sons; 2004.
49. Goldstein H. *Multilevel statistical models*. Kendall's library of statistics. Vol 3. Arnold; 2003:253.
50. Bécares L, Nazroo J, Jackson J, Heuvelman H. Ethnic density effects on health and experienced racism among Caribbean people in the US and England: a cross-national comparison. *Soc Sci Med*. 2012;75(12):2107-2115. doi:10.1016/j.socscimed.2012.03.046
51. Bécares L, Nazroo J, Stafford M. The buffering effects of ethnic density on experienced racism and health. *Health Place*. 2009;15(3):670-678. doi:10.1016/j.healthplace.2008.10.008
52. Gohar J, Do WL, Miller-Kleinhenz J, et al. Neighborhood characteristics and breast tumor methylation: using epigenomics to explore cancer outcome disparities. *Breast Cancer Res Treat*. 2022;191(3):653-663. doi:10.1007/s10549-021-06430-1

SUPPLEMENT.**eMethods.** Race and Ethnicity Data From the New Jersey State Cancer Registry**eResults.** Statistical Tests of Race-Ethnicity * HOLC Grade Interactions**eTable 1.** Observed Distributions of Breast Tumor Factors by Historical HOLC Grade and Race-Ethnicity, New Jersey, 2008-2017 (n=14,964)**eTable 2.** Imputed Distributions of Breast Tumor Factors by Historical HOLC Grade and Race-Ethnicity, New Jersey, 2008-2017 (n=374,100)