

Race and Ethnicity, Structural Racism and Timely Breast Biopsy

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Abstract

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Background: Minority race and ethnicity are often associated with delays in breast cancer diagnosis and treatment. Structural racism may contribute to such delays and may prove to be an important target for interventions to reduce disparities in healthcare delivery.

Methods: We conducted a single institution retrospective cohort study of 1938 women, 18 years old or older who received a screening mammogram and a subsequent recommendation for breast biopsy. We conducted unadjusted and adjusted logistic regression analyses to determine the relationship between race and ethnicity and nonreceipt of a breast biopsy within 30, 60, and 90 days. Adjusted models included woman-, neighborhood- and healthcare-level variables of

interest, including neighborhood-level measures of structural racism such as historical redlining. We also sought to quantify the relative importance of these multilevel factors in predicting nonreceipt of biopsy using a variable importance analysis.

Results: In unadjusted logistic regression models, Black women had higher odds of not receiving a breast biopsy within 30, 60, or 90 days (OR [95% CI]; 30 days: 2.27 [1.63,3.15], 60 days: 2.53 [1.72, 3.73], 90 days: 2.16 [1.37, 3.42]). After adjustment for multilevel variables, Black women continued to have greater odds of not receiving a timely biopsy (OR [95% CI]; 30 days: 1.96 [1.35, 2.83], 60 days: 2.31 [1.35, 2.83], 90 days: 2.1 [1.50,3.55]). Neighborhood-level variables, such as historical redlining, were not associated with nonreceipt of biopsy in the multivariable regression. However, in an unadjusted logistic regression model of historical redlining on nonreceipt of biopsy within 30 days of abnormal screening, living in “C” grade neighborhoods was associated with greater odds of not receiving a biopsy compared to living in an “A” grade neighborhood (OR [95% CI]; 4.11 [1.18,14.28]). Further sensitivity analyses limited to women living within graded neighborhoods showed that Black women had no significant difference in odds of not receiving a biopsy compared to White women and historical redlining was significantly associated with receipt of biopsy within 60 and 90 days ($p = 0.39$ and $p = 0.45$, respectively). Variable importance analyses did not identify any variables having importance measure estimates greater than 0 in accurately predicting nonreceipt of biopsy.

Conclusion: Black women with a recommendation for breast biopsy had greater odds of not receiving a biopsy within 30, 60, or 90 days when compared to White women. While initial analyses failed to detect any neighborhood-level variables as significantly associated with nonreceipt of biopsy, neighborhood historical redlining was associated with nonreceipt of biopsy in an adjusted sensitivity analysis limited to women living in neighborhoods graded “A”- “D.”

Future work including more patients living within neighborhoods assessed by the Home Owners' Loan Corporation are needed to better characterize the role of neighborhood redlining on racial and ethnic disparities in timely delivery of breast biopsies after an abnormal screening mammogram.

Race and Ethnicity, Structural Racism and Timely Breast Biopsy

Introduction

Breast cancer is the most diagnosed noncutaneous cancer among women in the United States.¹ With widespread implementation of routine screening mammography and treatment advances, breast cancer mortality has decreased by 42% since 1989.² Screening mammography contributes to lower breast cancer mortality by detecting cancers when they are earlier stage and more amenable to curative treatment.³ A modeling study evaluating the relative contributions of screening and treatment, found that mammographic screening reduced breast cancer mortality by 7 to 23 percent.⁴

However, prior to a screen-detected breast cancer diagnosis and definitive treatment, patients must obtain additional diagnostic evaluation following an abnormal screening mammogram. First, patients may need additional diagnostic imaging with mammography, ultrasound, or both. Any persistent suspicious findings on these diagnostic examinations require tissue sampling for a histologic diagnosis, usually obtained through an imaging-guided biopsy.⁵ Delays of 6 to 12 months during this diagnostic work-up period are associated with a higher risk of regional nodal metastases and larger tumors.⁶ Even when women have a shorter diagnostic period of several weeks, they report experiencing clinically significant anxiety and distress.^{7,8}

Racial and ethnic minority women diagnosed with screen-detected and symptomatic breast cancers often experience a greater burden of long delays prior to breast cancer diagnosis and definitive treatment. These delays are often associated with worse breast cancer outcomes.⁹⁻

¹¹ For example, Collin et al. found that among Black and White women diagnosed with cancer, Black women experienced longer delays to definitive surgical treatment and higher breast cancer

mortality, but racial disparities in mortality were lower among women without delay to surgery.¹⁰ A smaller study specifically evaluating screen-detected breast cancers from the same state cancer registry also found that Black women were more likely to experience longer intervals from screening to diagnosis compared to White women and women with delays of ≥ 45 days had higher odds of breast cancer mortality.¹² Delays experienced by women from racial and ethnic minority groups during the diagnostic period may be influenced by several multilevel factors.^{13,14} Specifically, persistent differences in receipt of a timely biopsy across racial and ethnic groups despite adjusting for individual-, neighborhood-, and healthcare-level factors are suggestive of other factors such as structural racism playing a role in these observed differences.¹⁵ However, studies often do not include specific measures of structural racism to test this hypothesis.

To better address racial disparities in delivery of healthcare services and potential subsequent outcomes, inclusion of appropriate measures of structural racism in health disparities research is of growing interest and development.^{16,17} Some of these suggested measures are based on the historical laws and policies that perpetuated racial segregation and housing discrimination in communities across the nation.¹⁸ For example, neighborhood-level measures of historical redlining—a practice that excluded Black Americans from obtaining Home Owners' Loan Corporation mortgages by judging them as “too risky”—have been developed and used.^{19,20} While this government sanctioned mortgage lending discrimination ended decades ago, the impact remains today. Moazzam et al. found that historically redlined census tracts were less likely to meet cancer screening targets set by Healthy People 2030.²¹ Historical redlining is also associated with present-day neighborhood-level social determinants of health, where historically redlined communities have been shown to rank worse across several domains when compared to

neighborhoods that were historically categorized as the lowest risk by the Home Owners' Loan Corporation.²² Given this association, Area Deprivation Index (ADI) has been proposed to be an appropriate surrogate measure for the long-term impact of structural racism on a neighborhood.¹⁶

In this study, we aimed to determine the association between multilevel factors, including race and ethnicity and neighborhood-level measures of structural racism, and the outcome of completion of a recommended breast biopsy within 30 days after an abnormal screening mammogram using logistic regression. Additional analyses using a threshold of 60 days and 90 days were also performed. We hypothesize that historical redlining and ADI will be among the most meaningful predictors of receiving a recommended biopsy. This evaluation of neighborhood-level social determinants of health that reflect structural racism may inform future targeted anti-racist policy interventions to reduce delays in breast cancer diagnosis.

Methods

Study Setting, Data Sources, and Participants

We performed a retrospective cohort study using clinical breast imaging data collected by the Northwest Screening and Cancer Outcomes Research Enterprise (NW-SCORE). NW-SCORE is a regional breast imaging registry that collects examination-level data from radiology practices located in the Pacific Northwest of the United States (specifically, Alaska, Montana, Oregon, Washington). These examination-level data are linked to cancer registry data, which will facilitate future research on breast imaging and associated breast cancer outcomes. This research was approved by the University of Washington Institutional Review Board and all procedures were Health Insurance Portability and Accountability Act compliant. We followed

the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines.²³

We analyzed data from abnormal screening mammograms performed on women 18-79-years-old performed from January 1, 2010, to December 31, 2020, that ultimately received a BI-RADS 4 or 5 final assessment, indicating a recommendation for tissue sampling.²⁴ Included examinations were obtained across 5 sites at a single institution. Women with a personal history of breast cancer were included in the analysis. We excluded mammograms if the woman's race and ethnicity were missing, if a valid residential address in the United States was unable to be successfully geocoded to a census block group, or if ADI was missing (Figure 1).

Outcome

The outcomes of interest were not receiving a recommended biopsy within 30, 60 or 90 days of an abnormal screening mammogram within the study institution. Currently, there is no broad consensus for recommended time to breast biopsy following a screening mammogram in the United States. Registry data from participating breast imaging practices across the United States show that >90% of institutions averaged less than 13.5 business days between screening and diagnostic imaging and less than 13.7 business days between diagnostic imaging and a biopsy, suggesting that receipt of a breast biopsy within 30 days is a relevant time point based on real world performance.²⁵ Alternatively, the National Breast and Cervical Cancer Early Detection Program performance metrics indicate that at least 75% of abnormal screening mammograms should receive a final diagnosis within 60 days.²⁶

Exposure Variables

Individual-level variables of interest included women's self-reported racial and ethnic group provided on questionnaires at the time of screening: American Indian or Alaskan Native, Asian non-Hispanic (hereafter, "Asian"), Black non-Hispanic (hereafter "Black), Hispanic (any race), White non-Hispanic (hereafter, "White") individuals, multiracial or "other". Additional individual-level factors obtained from the screening questionnaire completed by patients or the breast imaging report: age in years, family history of breast cancer (e.g., yes, or no/missing), personal history of breast cancer (e.g., yes or no/missing), personal history of a previous breast biopsy (e.g., yes, or no/missing), and breast density (almost entirely fatty, scattered areas of fibroglandular density, heterogeneously dense, and extremely dense). These variables were included as they are risk factors for breast cancer and may influence healthcare utilization decisions.²⁷ Although individual-level social determinants of health such as self-reported educational attainment, income, and insurance status important factors can impact healthcare access and utilization, such data were unavailable for inclusion in the analysis.²⁸⁻³⁰

Exposure variables of interest also included neighborhood-level social determinants of health related to structural racism. We included living within a historically redlined neighborhood as a measure of explicit structural racism. The redlining status of a neighborhood was based on the federal government's Home Owners' Loan Corporation descriptions of area-level "mortgage security" from the 1930s-1940s mapped to 2010 census tracts.³¹ Area descriptions included: "A" (i.e. "Best"), "B" (i.e. "Still Desirable"), "C" (i.e. "Definitely Declining"), "D" (i.e. "Hazardous" or redlined as indicated by the color red on maps). Many present-day neighborhoods are in areas not assigned a residential grade "A"- "D" due to being in a business/industrial region of a city or areas outside graded metropolitan areas at the time maps were created and are considered "ungraded." We also included neighborhood-level Area

Deprivation Index (ADI) as a potential surrogate measure of structural racism. This composite measure includes social determinants of health indicating neighborhood-level disadvantage at the census block group level and has been shown to be associated with various health outcomes.³² We used the 2015 Block Group ADI Files version 3.0, based on 2011-2015 ACS data.³³ Although newer ADI data from 2020 and 2021 are available, we chose the 2015 version to align with 2010 Census block group geographies used for all neighborhood-level variables in this study. In addition, the 2015 ADI file reflects data that more closely overlap with our selected variables derived from the 2017 ACS estimates. We chose 2017 ACS 5-year estimates because this period approximates the chronological midpoint for the examination data analyzed in the study.

Other neighborhood-level social determinants of health included in the analysis were calculated using protocols acquired from the PhenX Toolkit for Structural Social Determinants of Health based on the American Community Survey (ACS) data.³⁴ We selected census tract-level educational attainment, using the percentage of adults age 25 years and older with a Bachelor's degree or higher.¹⁷ We also included a binary indicator of census tract level concentrated poverty, which is defined as an area with greater than 40% of households living below the federal poverty threshold.³⁵ Educational attainment and concentrated poverty status were based on 2017 ACS 5-year estimates (2013-2017). We also included the rural-urban status based on Rural-Urban Commuting Area (RUCA) codes which are based on population density, urbanization, and daily commuting at the census tract level.³⁶ We used the most recent RUCA codes available, which were based on the 2010 decennial census and the 2006-2010 ACS data.

Although all imaging examinations were obtained from the same institution, they were performed at 5 different facilities, and this was included as a healthcare-level variable of interest.

Geocoding

We linked neighborhood-level social determinants of health to each mammogram after geocoding the patient's most recent address obtained from the electronic health record. We geocoded patient addresses for each mammogram examination in the NW-SCORE database in ArcGIS Desktop version 10.8.2 (Esri, Redlands, CA) using ArcGIS Business Analyst Desktop USA Street Address locator. To endure high quality geocoding, we set the minimum match score to 80 and manually reviewed and corrected matched addresses with scores less than 90, if necessary.³⁷ We reviewed addresses with tied scores and selected appropriate matches, if available, and unmatched inappropriately matched addresses. We also reviewed unmatched addresses to correct any typographical errors in the address to facilitate appropriate matches. We cleaned addresses before and during the geocoding process.

We spatially joined the resulting successfully matched geocoded addresses to ArcGIS Business Analyst ACS block group data to link each address to its census block group geographic identifier (Census Bureau Federal Information Processing Series code). Given the nested nature of the Federal Information Processing Series (FIPS) codes, we derived census tract codes from the block group FIPS code to facilitate data linkages, which were performed using R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

Statistical Analysis

We evaluated the association between racial and ethnic categories and the other explanatory variables using Fisher's exact test and a p-value of < 0.05 was considered significant. We performed an unadjusted and adjusted logistic regression of race on nonreceipt of recommended image guided biopsy within 30, 60 or 90 days. The adjusted model included the

multilevel variables described above. Self-reported race and ethnicity were included as a categorical variable, where American Indian/Alaska Native, Multiracial, and all others were combined into an “Other” category due to low numbers in each group. We specified age at the time of screening as a categorical variable, with the following categories: age <40, 40-49, 50-59, 60-69, 70+. Rather than including age as a continuous variable, these clinically relevant age categories were selected, in part, because they reflect age-based screening guidelines that recommend screening mammography begin at age 50 and support shared decision-making for women aged 40-49.³⁸ Categorizing age by decade also improves the interpretation of results in a manner that could guide interventions if results are meaningful. Breast density was included as a categorical variable including the four BI-RADS density categories and an “unknown” category for examinations without an associated density descriptor. Family history of breast cancer, personal history of breast cancer and personal history of breast biopsy were binary variables where patients endorsing such history were coded as “yes” and all others were coded as “no.” Of note, the method of data collection inconsistently distinguished negative histories from those with missing responses thus both were included in the “no” category. The redlining variable was a categorical variable with 5 levels, including “A”, “B”, “C”, “D”, and ungraded areas. Neighborhood educational attainment was included as a continuous variable of the percentage of adults 25 years and older who have attained a bachelor’s degree.¹⁷ Concentrated poverty status of a neighborhood was a binary variable with neighborhoods having more than 40% of households living below the poverty line were considered as having concentrated poverty. Given our small sample size, ADI was included as a binary indicator where neighborhoods having a national rank among the most disadvantaged 15% of neighborhoods were considered “high disadvantage” neighborhoods and the remaining 85% considered “low disadvantage”.³⁹ Rural-urban status of

neighborhoods was specified using the most common four category scheme (e.g., urban, large rural, small rural and isolated rural) based on aggregated RUCA codes.⁴⁰ Facility was a categorical variable including each of the 5 facilities that performed imaging. Adjusted analyses included year as a continuous variable to account for secular changes throughout the study period.

To help identify potential high-yield targets for intervention, we then performed a “variable importance analysis” to understand how each variable and level of influence (group of variables) contributes to prediction of nonreceipt of biopsy within 30, 60, and 90 days. We chose classification accuracy as our variable importance measure as it is an intuitive ratio of correct model predictions to total predictions.⁴¹ In this approach, the variable importance measure is defined as the population-level difference in classification accuracy of the best performing machine learning model predicting our outcome where all variables are included and the classification accuracy of the model including all variables except the variable/set of variables being assessed.⁴² If the removal of a variable or set of variables from the model results in a large loss of predictiveness (classification accuracy), such variables would be considered more important than a set a variables that do not result in a large loss of predictiveness when removed from the model. We computed point estimates, 95% confidence intervals and p-values for the null hypothesis that the variable importance measure is 0 (i.e., the variable has zero importance).

Additional post hoc analyses were performed. First, an unadjusted logistic regression model of redlining on receipt of biopsy within 30, 60, or 60 days was performed to understand this relationship in the absence of possible confounders in the model. In addition, we performed a sensitivity analysis of the adjusted logistic regression model, restricting observations to those having a redlining grade of “A” through “D” (i.e., excluding women living in areas that do not

correspond to a neighborhood graded on the available redlining maps). We removed ADI and rural-urban status from this model because all remaining observations were in urban, low deprivation neighborhoods. And finally, we assessed the correlation of the variables included in the model to allow us to determine whether the a priori adjusted logistic regression models in may have been over-adjusted for structural racism. We obtained the following strength of association measures: bias corrected Cramer's V for categorical vs. categorical variables, multiple correlation coefficients using ANOVA for categorical vs. numeric variables, and the Spearman correlation test for numeric vs. numeric variables.^{43,44}

All statistical analyses were performed using R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Cohort Description

Our final cohort included 1938 examinations from 1891 unique women. Of the entire cohort, 76.9% identified as White (1490/1938). Most women's geocoded addresses were in ungraded neighborhoods (i.e., located outside the regions assessed on the available Home Owners' Loan Corporation maps; 76.4%), while only 2.9% were in historically redlined communities. Only 0.7% of women (13/1938) lived in neighborhoods in the highest 15% of disadvantage based on national rank. Woman-level variables that varied across racial and ethnic groups included age at screening, breast density, and family history of breast cancer (p-values range <0.001-0.001). Neighborhood-level factors that varied across racial and ethnic groups included historical redlining and educational attainment (p-value <0.001). Table 1 summarizes the characteristics for each examination or associated woman.

Unadjusted Logistic Regression

In the unadjusted logistic regression, Black women had 2.27 times higher odds of not receiving a biopsy within 30 days of their abnormal screening mammogram compared to White women (OR [95% CI; p-value], 2.27 [1.63,3.15]; Table 2). Asian and Hispanic women also had greater odds of not receiving a biopsy within 30 days of abnormal screening (OR [95% CI; p-value]; Asian: 1.6 [1.14, 2.25]; Hispanic: 1.58 [1.04,2.39]). Black women had persistent higher odds of not receiving a biopsy within 60 and 90 days of abnormal screening (OR [95% CI; p-value]; 60 days: 2.53 [1.72, 3.73]; 90 days: 2.16 [1.37, 3.42]). The odds of Asian and Hispanic women not receiving a biopsy within 60 and 90 days of their abnormal screening was not significantly different compared to White women.

Multivariable Logistic Regression

In our analyses adjusting for multilevel factors, including measures of structural racism, we found that Black women had greater odds of not receiving a timely biopsy after an abnormal screening mammogram compared to white women. For example, Black women had 1.96 [CI: 1.35, 2.83] times higher odds of not receiving a biopsy within 30 days compared to White women (Table 3). We found similar results when assessing receipt of biopsy within 60 and 90 days (OR [95% CI]; 60 days: 2.31 [1.35, 2.83], 90 days: 2.1 [1.50,3.55]; Table 4 and 5). Women in the “Other” category had greater odds of not receive a biopsy within 60 days compared to White women (OR [95% CI]: 3.8 [1.24,10.5]).

We found that women-level factors of personal history of breast cancer and history of breast biopsy were associated with lower odds of not receiving a biopsy within 30, 60 or 90 days. Women reporting a personal history of breast cancer or prior breast biopsy had lower odds of not

receiving a biopsy within 30 days after their abnormal screening mammograms compared to those without such a history (OR [95% CI]: 0.42 [0.25, 0.70] for those with a history of breast cancer and 0.58 [0.46,0.72] for women receiving a prior biopsy). This relationship persisted when assessing nonreceipt of biopsy within 60 and 90 days. Patients with a family history of breast cancer had lower odds of not receiving a biopsy within 30 days of their screening examination (OR [95% CI]: 0.73 [0.58, 0.91]). However, this difference was not significant when assessing no receipt of biopsy within 60 or 90 days. Age category at screening was not associated with the odds of not receiving a biopsy within 30, 60, or 90 days of screening.

We did not find any statistically significant association between neighborhood-level social determinants of health and nonreceipt of biopsy within 30, 60, or 90 days of abnormal screening (Tables 3-5). For example, the women living in historically redlined neighborhoods had 2.16 greater odds of not receiving a biopsy within 30 days, however the confidence interval included the null value and the p-value = 0.3 > 0.05. Similarly, women living in high ADI neighborhoods had 2.98 greater odds of not receiving a timely biopsy, however this result was not statistically significant (p=0.078).

In most cases, receiving a screening mammogram at a facility other than facility “1” (the highest volume facility) was associated with higher odds of not receiving a biopsy within 30 days (OR [95% CI]: 1.81 [1.37,2.39] for facility “2”, 2.81 [2.13, 3.71] for facility “3”, and 2.96 [1.94, 4.51] for facility “4”). Similar results were found for biopsy within 60 days, and facility remained significantly associated with not receiving a biopsy within 90.

Variable Importance Measure Analysis

In our variable importance analysis, we did not find any of our selected variables to have variable importance measure estimates greater than 0 at a significance level of 0.05 in predicting receipt of a breast biopsy more than 30, 60 or 90 days after an abnormal screening mammogram (Table 6). Similarly, we did not find any variables grouped by level of influence (woman-, neighborhood-, or healthcare-level) to have a variable importance measure greater than 0 in predicting a delay to biopsy.

Post hoc Analyses

In our post hoc unadjusted logistic regression analysis of historical redlining on timely biopsy, we found that women living in grade “C” neighborhoods had higher odds of not receiving a breast biopsy within 30 days compared to women living in grade “A” neighborhoods (OR [95% CI]; 4.11 [1.18,14.28]; Table 2). Women living in neighborhoods not graded on available Home Owners’ Loan Corporation maps also had higher odds of not receiving a breast biopsy within 30 days of their abnormal screening mammogram (OR [95% CI]: 3.81[1.15,12.65]). There was no significant difference in nonreceipt of biopsy within 60 or 90 days of abnormal screening by neighborhood redlining.

In the multivariable logistic regression analyses of the study cohort limited to 458 women living in neighborhoods graded on historical Home Owners’ Loan Corporation maps, we found that racial and ethnic category was not associated with nonreceipt of biopsy within 30, 60, or 90 days of an abnormal screening mammogram (Tables 7-9). Specifically, Black women’s odds of not receiving a breast biopsy with 30, 60, or 90 days was not significantly higher than White women (OR [95%CI]: 1.12 [0.51,2.43] at 30 days, 1.36 [0.52, 3.53] at 60 days and 1.17 [0.39, 3.44] at 90 days from screening). Historical redlining was associated with not receiving a biopsy within 60 and 90 days from abnormal screening (p-values 0.039 and 0.045, respectively).

In correlation testing of the variables, most variables were either not correlated or only weakly correlated with one another (range: 0-0.26; Table 10). However, we found that historical redlining was moderately correlated with neighborhood-level college attainment. The year of screening examination was also moderately associated with facility.

Discussion

In this single institution study, we found that Black women had significantly higher odds of not receiving a biopsy within 30, 60 or 90 days of an abnormal screening mammogram compared to White women in our unadjusted logistic regression analyses. Adjustment for our selected multilevel factors, including neighborhood historical redlining, did not result in a substantial change in the odds of not receiving a biopsy within any specified time. For example, in the unadjusted analysis, Black women had 2.53 times higher odds of not receiving a biopsy within 60 days of their abnormal screening, the benchmark suggested by the National Breast and Cervical Cancer Early Detection Program. After adjustment for individual-, neighborhood-, and healthcare-level factors, Black women had persistent 2.31 times higher odds of not receiving a biopsy within 60 days of abnormal screening.

Our findings of Black women having higher odds of a delayed biopsy are consistent with prior studies showing Black women often experience longer time to diagnostic evaluation and breast biopsy. For example, in an unadjusted analysis of breast imaging registry data from January 2008 through December 2021, the median time from screening mammogram to documented additional diagnostic evaluation was 14 days for Black women compared to 9 days for White women. In the same study only 71.5% of Black women were documented as having completed a recommended breast biopsy and the median time to biopsy among Black women was 25 days (compared to 21 days for White women).⁴⁵ In previous work adjusting for

multilevel factors (not including the structural racism measures of redlining or ADI), there were small changes in relative risk of not receiving a timely biopsy (unadjusted relative risk of not receiving a biopsy in 60 days for Black women compared to White women 1.39 vs adjusted relative risk 1.28).¹⁵

Despite prior studies demonstrating an association between ADI or historical redlining and healthcare utilization or cancer outcomes,^{14,46-48} we did not identify statistically significant association between historical redlining and time to biopsy in our a priori adjusted regression models. In our small population, 2.9% of women lived in historically redlined neighborhoods and only 0.7% of women lived in highly disadvantaged neighborhoods, which may have limited our ability to detect statistically significant differences among these populations. In addition, we had a large proportion of women living outside of areas historically assessed for mortgage lending programs, further limiting the assessment of neighborhood-level redlining.

To further evaluate the relationship between race and ethnicity, structural racism and nonreceipt of a timely biopsy, we performed additional analyses. In an unadjusted logistic regression of historical redlining on time to biopsy, we found that women living in “C” grade or ungraded neighborhoods had higher odds of not receiving a biopsy within 30 days of abnormal screen. In our multivariable logistic regression analyses limited to 458 women living in neighborhoods assigned a redlining grade of A-D, we found that Black women did not have statistically significant higher odds of not receiving a biopsy within 30, 60 or 90 days of abnormal screening compared to White women. Furthermore, historical redlining was associated with the outcome of nonreceipt of biopsy within 60 and 90 days of abnormal screening in these analysis (p-values = 0.039 and 0.045, respectively). Together, these findings suggest that historical redlining may play a role in women not receiving a biopsy within specific time periods

in addition to race and other individual-level variables. However, future studies including larger populations living entirely within graded areas could be performed to further assess the impact of historical neighborhood redlining on breast imaging performance metrics.

After assessing for associations between our multilevel variables of interest and the outcomes of interest, we sought to measure the relative importance of each variable included in our logistic regression in predicting our outcomes and establish a ranking of important variables. Identifying variables of greatest importance has the potential to highlight factors that are most important to prioritize in any targeted intervention to reduce relative delays to biopsy. Despite finding a few individual-level factors (i.e., self-reported race, history of breast cancer, and history of breast biopsy) associated with our outcomes in our logistic regression analyses, we did not identify any variables as having importance statistically significant from zero in the variable importance analysis (i.e., factors were not important features in machine learning models predicting the outcome of no biopsy). As we were unable to define the importance of any variable as greater than zero, we were also unable to effectively rank these variables by importance. Correlation between variables of interest is known to limit the ability to identify significant importance of variables, however, we only found moderate correlation between just a few of the variables.⁴² One recommended approach to mitigate this specific challenge is to group variables we would expect to be correlated given established evidence. However, even the planned group-level analysis of variable importance failed to result in statistically significant results (i.e., despite grouping likely correlated neighborhood-level variables).

Limitations

Our study has several limitations. First, 34% (1,016/2,954) of otherwise eligible women with missing race or residential address were not included in the study cohort given the study's

primary aim of identifying racial and ethnic and neighborhood-level factors associated with differences in time to biopsy. Our small sample size, at a single institution in a single metropolitan area may have limited our ability to detect differences in receipt of timely biopsy by our neighborhood-level socioeconomic factors. Furthermore, exclusion criteria may have resulted in systematic omission of certain patients, such as rural dwelling women who primarily use a PO box or homeless women unable to provide any address. In addition, the addresses geocoded for this study represented the most recent address at the time the data was obtained regardless of patients' home address when they obtained the screening mammogram. Thus, the neighborhood-level factors included in the analyses do not account for change in neighborhood residence over time. Beyond limitations related to geocoding, our analysis did not include many relevant individual-level social determinants of health such as women's educational attainment, household income or insurance status due to limited collection of such data. And finally, patients who were recommended for biopsy but were determined to have a benign finding at the time of scheduled biopsy (and thus had a cancelled biopsy) or had a biopsy at another institution were classified as not having a timely biopsy although they may have ultimately received a biopsy elsewhere or no longer needed a biopsy. Information to distinguish such cases was unavailable from the registry.

Conclusions

We performed multivariable regression analyses of data from a large academic radiology department to evaluate the association between race and ethnicity, structural racism, and timely breast biopsy after an abnormal screening mammogram. Although our initial analyses found that Black women in particular experienced higher odds of not receiving a breast biopsy within 30, 60, or 90 days of an abnormal screen before and after adjusting for multilevel factors,

neighborhood-level social determinants of health were not significant. However, additional multivariable analysis on a subset of women living in neighborhoods graded “A”-“D”, found some evidence that historical redlining was significantly associated with nonreceipt of a biopsy within 60 or 90 days. Future studies including more patients living within neighborhoods assessed by the Home Owners’ Loan Corporation are needed to better characterize the role of race and ethnicity and neighborhood redlining in timely delivery of breast biopsies after an abnormal screening mammogram.

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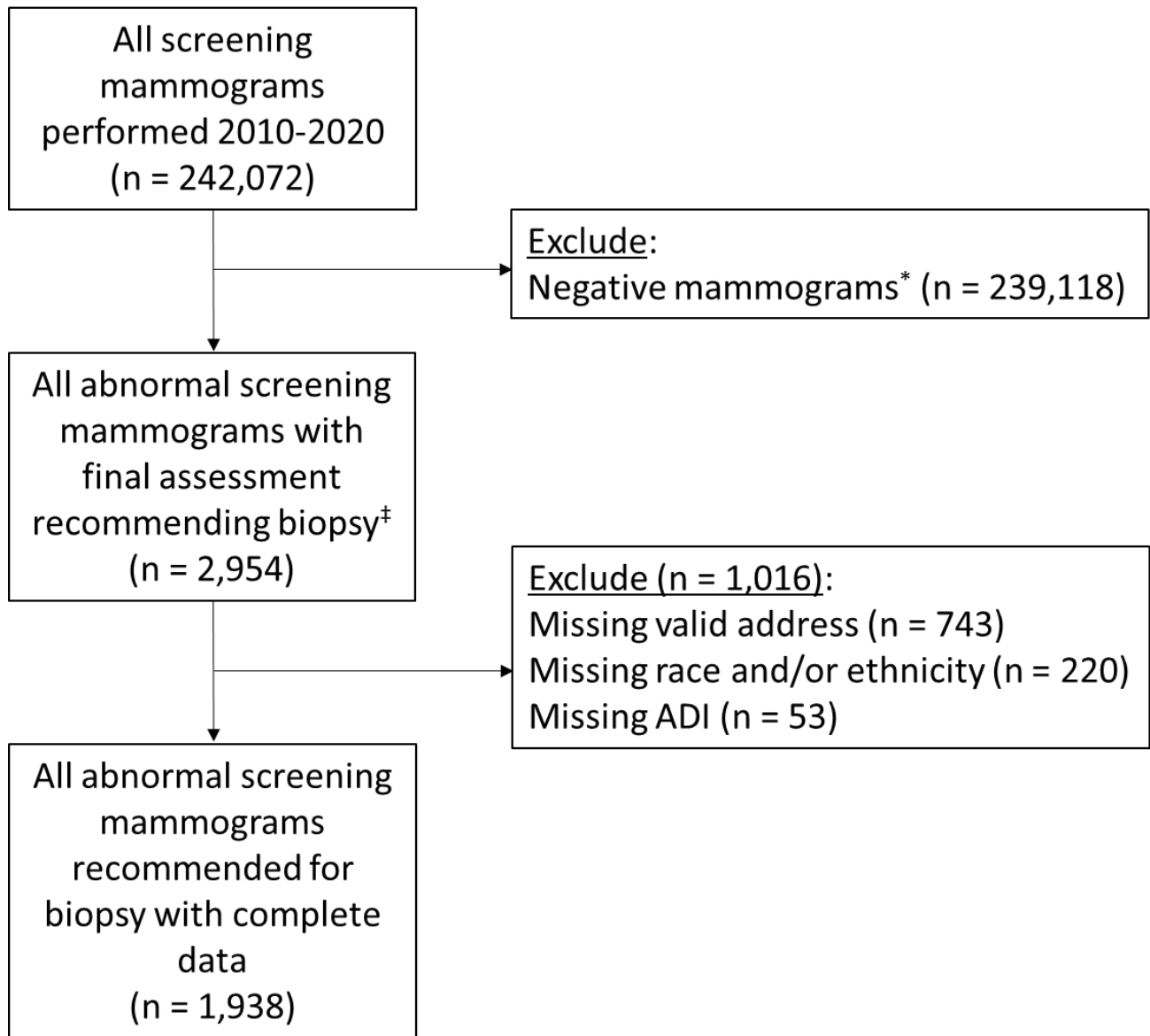
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Tables and Figures

Figure 1. Consort Diagram of Cohort Selection



* Final assessment: BI-RADS 1, 2, or 3 on subsequent diagnostic evaluation

‡ Final assessment: BI-RADS 4 or 5 on subsequent diagnostic evaluation

Urban	161 (100%)	161 (99.4%)	106 (99.1%)	1430 (96.0%)	17 (94.4%)	1875 (96.7%)	
Large Rural	0 (0%)	1 (0.6%)	0 (0%)	33 (2.2%)	1 (5.6%)	35 (1.8%)	
Small Rural	0 (0%)	0 (0%)	1 (0.9%)	14 (0.9%)	0 (0%)	15 (0.8%)	
Isolated Rural	0 (0%)	0 (0%)	0 (0%)	13 (0.9%)	0 (0%)	13 (0.7%)	
Facility							<0.001
1	43 (26.7%)	58 (35.8%)	25 (23.4%)	550 (36.9%)	8 (44.4%)	684 (35.3%)	
2	45 (28.0%)	24 (14.8%)	14 (13.1%)	455 (30.5%)	4 (22.2%)	542 (28.0%)	
3	65 (40.4%)	69 (42.6%)	60 (56.1%)	300 (20.1%)	5 (27.8%)	499 (25.7%)	
4	3 (1.9%)	10 (6.2%)	8 (7.5%)	154 (10.3%)	1 (5.6%)	176 (9.1%)	
5	5 (3.1%)	1 (0.6%)	0 (0%)	31 (2.1%)	0 (0%)	37 (1.9%)	
* Fisher's exact test with p-values computed with Monte Carlo simulation							

Table 2. Unadjusted Odds Ratios of Nonreceipt of Biopsy within 30, 60, and 90 days by Race and Ethnicity and Historical Redlining

	No Biopsy within 30 days			No Biopsy within 60 days			No Biopsy within 90 days		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Race and Ethnicity									
Asian, non-Hispanic	1.6	1.14, 2.25	0.007	1.44	0.92, 2.25	0.11	0.83	0.44, 1.57	0.6
Black, non-Hispanic	2.27	1.63, 3.15	<0.001	2.53	1.72, 3.73	<0.001	2.16	1.37, 3.42	<0.001
Hispanic	1.58	1.05, 2.39	0.028	1.61	0.96, 2.71	0.072	0.79	0.36, 1.74	0.6
White, non-Hispanic	Reference	Reference		Reference	Reference		Reference	Reference	
Other	2.21	0.86, 5.64	0.1	3.73	1.38, 10.07	0.009	2.26	0.64, 7.93	0.2
Historical Redlining									
A	Reference	Reference		Reference	Reference		Reference	Reference	
B	2.96	0.86, 10.12	0.084	3.38	0.44, 25.91	0.2	2.79	0.36, 21.50	0.3
C	4.11	1.18, 14.28	0.026	7.00	0.91, 53.61	0.061	4.94	0.64, 38.25	0.13
D	3.38	0.90, 12.75	0.072	3.29	0.38, 28.71	0.3	1.56	0.15, 15.63	0.7
Ungraded	3.81	1.15, 12.65	0.029	4.58	0.62, 33.79	0.14	2.52	0.34, 18.62	0.4

Table 3. Multivariable Logistic Regression of No Biopsy within 30 days

Multilevel Factor	OR	95% CI	p-value
Race and Ethnicity			0.003
Asian	1.28	0.89, 1.85	
Black	1.96	1.35, 2.83	
Hispanic	1.38	0.88, 2.15	
White	Reference	Reference	
Other	2.36	0.87, 6.37	
Age at Screening			0.2
< 40	Reference	Reference	
40-49	1.12	0.45, 2.74	
50-59	1.1	0.45, 2.74	
60-69	1.49	0.61, 3.67	
70+	1.26	0.50, 3.18	
Breast Density			0.7
Almost entirely fatty	Reference	Reference	
Scattered fibroglandular densities	0.86	0.54, 1.36	
Heterogeneously dense	0.81	0.51, 1.28	
Extremely Dense	0.9	0.48, 1.69	
Unknown	0.65	0.34, 1.25	
Family History of Breast Cancer			0.006
No	Reference	Reference	
Yes	0.73	0.58, 0.91	
Personal History of Breast Cancer			<0.001
No	Reference	Reference	
Yes	0.42	0.25, 0.70	
History of Breast Biopsy			<0.001
No	Reference	Reference	
Yes	0.58	0.46, 0.72	
Historical Redlining			0.3
A	Reference	Reference	
B	2.92	0.83, 10.31	
C	3.3	0.91, 11.95	
D	2.16	0.54, 8.62	
Ungraded	2.9	0.83, 10.12	
College Education Attainment	1	0.99, 1.00	
Neighborhood Concentrated Poverty			
No	Reference	Reference	0.7
Yes	0.87	0.40, 1.87	
Area Deprivation Index			0.079
Low Disadvantage	Reference	Reference	
High Disadvantage	2.98	0.88, 10.03	
Rural Urban Commuting Code			0.2
Urban	Reference	Reference	
Large Rural	0.35	0.11, 1.08	
Small Rural	0.93	0.27, 3.19	

Isolated Rural	0.49	0.10, 2.31	
Facility			
1	Reference	Reference	<0.001
2	1.81	1.37, 2.39	
3	2.81	2.12, 3.70	
4	2.96	1.94, 4.52	
5	0.9	0.33, 2.44	
Year	0.92	0.89, 0.95	
OR = Odds Ratio, CI = Confidence Interval			

Table 4. Multivariable Logistic Regression of No Biopsy within 60 days

Multilevel Factor	OR	95% CI	p-value
Race and Ethnicity			<0.001
Asian	1.27	0.79, 2.04	
Black	2.31	1.50, 3.55	
Hispanic	1.77	1.01, 3.10	
White	Reference	Reference	
Other	3.8	1.33, 10.87	
Age at Screening			0.7
< 40	Reference	Reference	
40-49	1.25	0.36, 4.38	
50-59	1.58	0.45, 5.49	
60-69	1.27	0.36, 4.45	
70+	1.39	0.39, 4.98	
Breast Density			0.2
Almost entirely fatty	Reference	Reference	
Scattered fibroglandular densities	0.57	0.33, 0.96	
Heterogeneously dense	0.51	0.30, 0.87	
Extremely Dense	0.48	0.22, 1.08	
Unknown	0.49	0.22, 1.08	
Family History of Breast Cancer			0.085
No	Reference	Reference	
Yes	0.77	0.57, 1.04	
Personal History of Breast Cancer			0.009
No	Reference	Reference	
Yes	0.43	0.22, 0.86	
History of Breast Biopsy			<0.001
No	Reference	Reference	
Yes	0.43	0.32, 0.57	
Historical Redlining			0.069
A	Reference	Reference	
B	3.55	0.45, 27.93	
C	6.55	0.82, 52.12	
D	2.55	0.28, 23.32	
Ungraded	4.43	0.57, 34.19	
College Education Attainment	1	0.99, 1.01	0.9
Neighborhood Concentrated Poverty			0.7
No	Reference	Reference	
Yes	1.21	0.44, 2.90	
Area Deprivation Index			>0.9
Low Disadvantage	Reference	Reference	
High Disadvantage	1.03	0.21, 5.03	
Rural Urban Commuting Code			0.7
Urban	Reference	Reference	
Large Rural	0.81	0.23, 2.83	
Small Rural	2.05	0.53, 7.99	

Isolated Rural	0.68	0.08, 5.44	
Facility			0.002
1	Reference	Reference	
2	1.48	1.02, 2.13	
3	1.66	1.16, 2.39	
4	2.39	1.37, 4.13	
5	0.35	0.05, 2.68	
Year	0.89	0.85, 0.94	<0.001
OR = Odds Ratio, CI = Confidence Interval			

Table 5. Multivariable Logistic Regression of No Biopsy within 90 days

Multilevel Factor	OR	95% CI	p-value
Race and Ethnicity			0.057
Asian	0.83	0.42, 1.63	
Black	2.1	1.25, 3.52	
Hispanic	0.95	0.41, 2.19	
White	Reference	Reference	
Other	2.2	0.58, 8.36	
Age at Screening (years)			0.4
< 40	Reference	Reference	
40-49	1.17	0.26, 5.30	
50-59	1.44	0.32, 6.42	
60-69	0.98	0.22, 4.44	
70+	1.47	0.32, 6.77	
Breast Density			0.2
Almost entirely fatty	Reference	Reference	
Scattered fibroglandular densities	0.57	0.31, 1.07	
Heterogeneously dense	0.5	0.26, 0.94	
Extremely Dense	0.3	0.10, 0.90	
Unknown	0.56	0.22, 1.40	
Family History of Breast Cancer			0.6
No	Reference	Reference	
Yes	0.92	0.64, 1.32	
Personal History of Breast Cancer			<0.001
No	Reference	Reference	
Yes	0.06	0.01, 0.45	
History of Breast Biopsy			<0.001
No	Reference	Reference	
Yes	0.26	0.18, 0.40	
Historical Redlining			0.085
A	Reference	Reference	
B	3.19	0.40, 25.41	
C	5.03	0.62, 40.8	
D	1.35	0.13, 14.4	
Ungraded	2.71	0.35, 21.3	
College Education Attainment	1	0.99, 1.01	0.9
Neighborhood Concentrated Poverty			0.6
No	Reference	Reference	
Yes	1.29	0.48, 3.43	
Area Deprivation Index			0.8
Low Disadvantage	Reference	Reference	
High Disadvantage	1.35	0.16, 11.5	
Rural Urban Commuting Code			>0.9

Urban	Reference	Reference	
Large Rural	0.87	0.19, 3.98	
Small Rural	0.91	0.11, 7.74	
Isolated Rural	0.99	0.12, 8.13	
Facility			0.04
1	Reference	Reference	
2	1.48	0.95, 2.29	
3	1.27	0.81, 1.99	
4	1.84	0.95, 3.56	
5	0	0.00, inf	
Year	0.9	0.85, 0.95	<0.001
OR = Odds Ratio, CI = Confidence Interval			

Table 6. Variable Importance Analysis Based on Classification Accuracy

No biopsy within 30 days of abnormal screening				
Factor	VIM	SE	95% CI	p-value
Race and Ethnicity	0	0.02057925	[0, 0.9998239]	0.6
Age at Screening	0	0.02045585	[0, 0.9898213]	0.7
Breast Density	0	0.02050267	[0, 0.9999993]	0.6
Family History of Breast Cancer	0.008230767	0.0205016	[6.042163e-05, 0.5326735]	0.3
Personal History of Breast Cancer	0	0.02046539	[0, 0.9999608]	0.6
History of Breast Biopsy	0.01348403	0.02047319	[0.0006688921, 0.2182099]	0.3
Historical Redlining	0.01245222	0.02039086	[0.0004886912, 0.2453885]	0.3
College Education Attainment	0.007675416	0.02054402	[3.912756e-05, 0.6045808]	0.4
Neighborhood Concentrated Poverty	0.000510423	0.02041848	[4.366365e-38, 1]	0.5
Area Deprivation Index	0	0.02039849	[0, 0.9559156]	0.7
Rural Urban Commuting Code	0	0.02048235	[0, 0.9663309]	0.7
Facility	0.004636107	0.02057717	[7.456782e-07, 0.9667699]	0.4
Year	0	0.02053309	[0, 0.9925581]	0.7
Group of Factors by Level of Influence				
Woman Level	0.02346588	0.02062486	[0.004100537, 0.1229921]	0.1
Neighborhood level	0	0.02050849	[0, 0.9999366]	0.6
Healthcare Level	0.006520224	0.02064495	[1.271321e-05, 0.7721069]	0.4
No biopsy within 60 days of abnormal screening mammogram				
Factor	VIM	SE	95% CI	p-value
Race and Ethnicity	0	0.01570484	[0, 0.9999946]	0.6
Age at Screening	0.001488095	0.01568027	[1.551247e-12, 0.9999993]	0.5
Breast Density	0	0.01568027	[0, 1]	0.5
Family History of Breast Cancer	0.00027921	0.01568032	[4.260855e-52, 1]	0.5
Personal History of Breast Cancer	0	0.01570384	[0, 0.9999952]	0.6
History of Breast Biopsy	0	0.01568027	[0, 1]	0.5
Historical Redlining	0	0.0157285	[0, 1]	0.5
College Education Attainment	0.001767305	0.01572947	[4.557779e-11, 0.9999855]	0.5
Neighborhood Concentrated Poverty	0.003996599	0.01570368	[1.759608e-06, 0.9014823]	0.4
Area Deprivation Index	0	0.01570494	[0, 1]	0.5
Rural Urban Commuting Code	0	0.01568027	[0, 1]	0.5
Facility	0.001767305	0.01568027	[4.813832e-11, 0.9999846]	0.5
Year	0.001767305	0.01568027	[4.813832e-11, 0.9999846]	0.5
Group of Factors by Level of Influence				
Woman Level	0	0.01568031	[0, 1]	0.5
Neighborhood level	0.002083333	0.01572879	[7.582792e-10, 0.999826]	0.4
Healthcare Level	0.000746897	0.01570392	[9.187963e-22, 1]	0.5
No biopsy within 60 days of abnormal screening mammogram				
Factor	VIM	SE	95% CI	p-value
Race and Ethnicity	0.00170068	0.01277912	[6.674755e-10, 0.9997701]	0.4
Age at Screening	0	0.01277885	[0, 0.9993505]	0.6
Breast Density	0.003401361	0.01277885	[2.109935e-06, 0.8466424]	0.4
Family History of Breast Cancer	0.001872502	0.01277915	[2.839192e-09, 0.9991939]	0.4

Personal History of Breast Cancer	0.003401361	0.01277885	[2.109935e-06, 0.8466424]	0.4
History of Breast Biopsy	0	0.01277921	[0, 1]	0.5
Historical Redlining	0.00170068	0.01277912	[6.674755e-10, 0.9997701]	0.4
College Education Attainment	0.000171821	0.01277922	[8.243586e-68, 1]	0.5
Neighborhood Concentrated Poverty	0	0.01277912	[0, 0.9999996]	0.6
Area Deprivation Index	0	0.01277921	[0, 1]	0.5
Rural Urban Commuting Code	0.001528859	0.01277911	[1.14628e-10, 0.9999511]	0.5
Facility	0	0.01277885	[0, 0.9993505]	0.6
Year	0	0.01277922	[0, 1]	0.5
Group of Factors by Level of Influence				
Woman Level	0	0.01277912	[0, 0.9999996]	0.6
Neighborhood level	0.003573182	0.0127789	[3.158708e-06, 0.802803]	0.4
Healthcare Level	0.003573182	0.0127789	[3.158708e-06, 0.802803]	0.4

Table 7. Post hoc Multivariable Logistic Regression of No Biopsy within 30 days Among Women Living in Neighborhoods Assessed by the Home Owners' Loan Corporation

Multilevel Factor	OR	95% CI	p-value
Race and Ethnicity			0.6
Asian	1.55	0.65, 3.71	
Black	1.12	0.51, 2.43	
Hispanic	0.84	0.26, 2.75	
White	Reference	Reference	
Other	5.44	0.45, 65.4	
Age at Screening			0.090
< 40	0.00	0.00, Inf	
40-49	Reference	Reference	
50-59	1.54	0.83, 2.87	
60-69	2.02	1.05, 3.90	
70+	1.72	0.78, 3.76	
Breast Density			0.5
Almost entirely fatty	Reference	Reference	
Scattered fibroglandular densities	0.66	0.21, 2.03	
Heterogeneously dense	0.50	0.16, 1.54	
Extremely Dense	0.38	0.09, 1.56	
Unknown	0.32	0.06, 1.77	
Family History of Breast Cancer			0.2
No	Reference	Reference	
Yes	0.71	0.44, 1.17	
Personal History of Breast Cancer			0.015
No	Reference	Reference	
Yes	0.25	0.07, 0.85	
History of Breast Biopsy			0.058
No	Reference	Reference	
Yes	0.62	0.38, 1.02	
Historical Redlining			0.3
A	Reference	Reference	
B	2.53	0.69, 9.23	
C	2.92	0.75, 11.4	
D	1.89	0.42, 8.58	
College Education Attainment	1.00	0.98, 1.01	0.7
Neighborhood Concentrated Poverty			0.6
No	Reference	Reference	
Yes	1.32	0.43, 4.09	
Facility			<0.001
1	Reference	Reference	
2	1.44	0.81, 2.55	
3	4.11	2.06, 8.19	
4	2.48	0.93, 6.63	
Year	0.96	0.89, 1.03	0.2
OR = Odds Ratio, CI = Confidence Interval			

Table 9. Post hoc Multivariable Logistic Regression of No Biopsy within 60 days Among Women Living in Neighborhoods Assessed by the Home Owners' Loan Corporation

Multilevel Factor	OR	95% CI	p-value
Race and Ethnicity			0.12
Asian	1.92	0.67, 5.47	
Black	1.36	0.52, 3.53	
Hispanic	0.50	0.06, 4.24	
White	Reference	Reference	
Other	19.9	1.56, 254	
Age at Screening			0.3
< 40	0.00	0.00, Inf	
40-49	Reference	Reference	
50-59	2.13	0.91, 5.01	
60-69	1.43	0.56, 3.67	
70+	2.21	0.79, 6.20	
Breast Density			0.3
Almost entirely fatty	Reference	Reference	
Scattered fibroglandular densities	0.39	0.11, 1.34	
Heterogeneously dense	0.29	0.08, 1.02	
Extremely Dense	0.17	0.03, 1.13	
Unknown	0.35	0.05, 2.56	
Family History of Breast Cancer			0.6
No	Reference	Reference	
Yes	0.84	0.44, 1.62	
Personal History of Breast Cancer			0.2
No	Reference	Reference	
Yes	0.35	0.07, 1.75	
History of Breast Biopsy			0.054
No	Reference	Reference	
Yes	0.52	0.27, 1.02	
Historical Redlining			0.039
A	Reference	Reference	
B	3.20	0.39, 26.3	
C	6.99	0.81, 60.2	
D	2.95	0.28, 30.6	
College Education Attainment	1.01	0.99, 1.03	0.3
Neighborhood Concentrated Poverty			0.5
No	Reference	Reference	
Yes	1.57	0.39, 6.37	
Facility			0.037
1	Reference	Reference	
2	1.62	0.73, 3.63	
3	3.05	1.23, 7.56	
4	3.95	1.12, 13.9	
Year	0.91	0.82, 1.00	0.058
OR = Odds Ratio, CI = Confidence Interval			

Table 10. Post hoc Multivariable Logistic Regression of No Biopsy within 90 days Among Women Living in Neighborhoods Assessed by the Home Owners' Loan Corporation

Multilevel Factor	OR	95% CI	p-value
Race and Ethnicity			0.2
Asian	0.84	0.21, 3.39	
Black	1.17	0.39, 3.44	
Hispanic	0.66	0.08, 5.75	
White	Reference	Reference	
Other	21.0	1.60, 275	
Age at Screening			0.053
40-49	Reference	Reference	
< 40	0.00	0.00, Inf	
50-59	3.03	1.16, 7.91	
60-69	1.20	0.38, 3.76	
70+	3.03	0.95, 9.66	
Breast Density			0.6
Almost entirely fatty	Reference	Reference	
Scattered fibroglandular densities	0.68	0.17, 2.76	
Heterogeneously dense	0.58	0.14, 2.35	
Extremely Dense	0.17	0.02, 1.94	
Unknown	0.38	0.03, 4.79	
Family History of Breast Cancer			0.3
No	Reference	Reference	
Yes	0.71	0.35, 1.46	
Personal History of Breast Cancer			0.008
No	Reference	Reference	
Yes	0.00	0.00, Inf	
History of Breast Biopsy			0.2
No	Reference	Reference	
Yes	0.61	0.29, 1.27	
Historical Redlining			0.045
A	Reference	Reference	
B	3.12	0.37, 26.1	
C	5.97	0.67, 53.4	
D	1.53	0.12, 18.9	
College Education Attainment	1.01	0.99, 1.04	0.4
Neighborhood Concentrated Poverty			0.8
No	Reference	Reference	
Yes	1.27	0.26, 6.10	
Facility			0.2
1	Reference	Reference	
2	1.10	0.46, 2.63	
3	2.50	0.92, 6.77	
4	2.29	0.55, 9.50	
Year	0.90	0.80, 1.00	0.055
OR = Odds Ratio, CI = Confidence Interval			

Table 10. Association Measure Matrix of Model Covariates

	Race and Ethnicity	Age	Density	Family History of Breast Cancer	Personal History of Breast Cancer	Biopsy History	Historical Redlining	College Attainment	Concentrated Poverty	ADI	Rural-Urban	Facility	Year
Race and Ethnicity	1	0.07	0.05	0.14	0	0	0.08	0.18	0.03	0.02	0.03	0.13	0.13
Age		1	0.12	0.03	0.07	0.11	0.02	0.08	0.06	0	0.17	0.08	0.17
Density			1	0.05	0.02	0.07	0.04	0.15	0	0	0.04	0.14	0.21
Family History of Breast Cancer				1	0.1	0.06	0	0.03	0.03	0	0.04	0.15	0.03
Personal History of Breast Cancer					1	0.1	0.02	0.05	0	0.06	0.03	0.06	0.02
Biopsy History						1	0	0.004	0.03	0.02	0.02	0.22	0.25
Historical Redlining							1	0.47	0.09	0.001	0.04	0.09	0.4
College Attainment								1	0.04	0.13	0.17	0.26	0.08
Concentrated Poverty									1	0.02	0.11	0	0.007
ADI										1	0.16	0.01	0.02
Rural-Urban											1	0.06	0.03
Facility												1	0.44
Year													1

Association measures of categorical variables are bias corrected Cramer's V, the correlation coefficients of categorical and numeric variables were obtained using ANOVA, and the correlation coefficients of 2 numeric variables were obtained using the Spearman correlation test.

ADI= Area deprivation index