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Guideline-concordant breast cancer care by patient race and ethnicity accounting for individual-, facility- and area-level characteristics: a SEER-Medicare study

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Abstract

Purpose—To examine racial–ethnic variation in adherence to established quality metrics (NCCN guidelines and ASCO quality metrics) for breast cancer, accounting for individual-, facility-, and area-level factors.

Methods—Data from women diagnosed with invasive breast cancer at 66+ years of age from 2000 to 2017 were examined using SEER-Medicare. Associations between race and ethnicity and guideline-concordant diagnostics, locoregional treatment, systemic therapy, documented stage, and oncologist encounters were estimated using multilevel logistic regression models to account for clustering within facilities or counties.

Results—Black and American Indian/Alaska Native (AIAN) women had consistently lower odds of guideline-recommended care than non-Hispanic White (NHW) women (Diagnostic

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workup: OR_{Black} 0.83 (0.79–0.88), OR_{AIAN} 0.66 (0.54–0.81); known stage: OR_{Black} 0.87 (0.80–0.94), OR_{AIAN} 0.63 (0.47–0.85); seeing an oncologist: OR_{Black} 0.75 (0.71–0.79), OR_{AIAN} 0.60 (0.47–0.72); locoregional treatment: OR_{Black} 0.80 (0.76–0.84), OR_{AIAN} 0.84 (0.68–1.02); systemic therapies: OR_{Black} 0.90 (0.83–0.98), OR_{AIAN} 0.66 (0.48–0.91)). Commission on Cancer accreditation and facility volume were significantly associated with higher odds of guideline-concordant diagnostics, stage, oncologist visits, and systemic therapy. Black residential segregation was associated with significantly lower odds of guideline-concordant locoregional treatment and systemic therapy. Rurality and area SES were associated with significantly lower odds of guideline-concordant diagnostics and oncologist visits.

Conclusions—This is the first study to examine guideline-concordance across the continuum of breast cancer care from diagnosis to treatment initiation. Disparities were present from the diagnostic phase and persisted throughout the clinical course. Facility and area characteristics may facilitate or pose barriers to guideline-adherent treatment and warrant future investigation as mediators of racial–ethnic disparities in breast cancer care.

Keywords

Health disparities; Health equity; Multilevel modeling; Race; Ethnicity; Cancer care continuum

Introduction

Racial and ethnic disparities in breast cancer survivor-ship emerged simultaneously with the dissemination of effective screening tools and therapies [1]. Differences in access to and quality of breast cancer care contribute to survival disparities and evidence suggests structural racism—not race—is the root cause [2, 3]. Racial residential segregation and unequal healthcare are two primary mechanisms through which structural racism creates health inequalities across a wide variety of outcomes, including breast cancer [2, 4–7]. Residential segregation and historic practices such as redlining served as a foundation for disinvestment in infrastructure and services critical to health and accessing healthcare, such as transportation and housing [2, 3]. Neighborhood factors and characteristics of healthcare facilities have demonstrated associations with quality of care and survival among breast cancer patients, indicating an opportunity to mitigate racial–ethnic disparities in outcomes by improving the quality and accessibility of cancer care [4, 8–22].

Clinical practice guidelines provide evidence-based recommendations for diagnosis and treatment of many conditions (including breast cancer) [23]. Provision of care concordant with guidelines is an important aspect of quality and is critical for patient outcomes, including significant reductions in risk of death among breast cancer patients [24–27]. However, Black and American Indian/Alaska Native (AIAN) women are less likely to receive guideline-recommended breast cancer treatment than White women [8–10, 12, 15, 28–38]. A study of breast and colorectal cancer patients documented decreasing adherence to quality metrics as the proportion of Black patients in a physicians' practice increased; providers who treated no Black patients had the highest rate of adherence [39]. Extant studies often focus on the point of treatment itself without examining failures in care delivery leading up to treatment and few examine guideline-concordance within the context of the constraints that shape patients' access to and quality of care.

In this study, we characterized variation in guideline-concordant diagnostic workup, known stage at diagnosis, oncologist encounters, locoregional treatment, and systemic therapy by race and ethnicity and facility and area characteristics. This work builds off our recently published study documenting disparities in receipt of evidence-based components of care by grouping individual services into summary measures of guideline-concordance at each phase of the care continuum and using multilevel modeling to account for the roles of facility and area-level factors in quality of care [40]. Understanding racial–ethnic variation in receipt of guideline-concordant care along the breast cancer care continuum from diagnostics to treatment initiation within the context of where patients seek care will elucidate mechanisms for intervention to increase access to high-quality care and mitigate disparities in outcomes.

Methods

Data source and study population

This retrospective cohort study utilized the Surveillance, Epidemiology, and End Results (SEER)-Medicare data linkage to identify women diagnosed with invasive breast cancer between 2000 and 2017. The SEER cancer file provided patient, tumor, and treatment information for patients diagnosed in the 18-site catchment area [41, 42]. We used Medicare enrollment and claims files, including race and vital status information, for 1999 through 2019. Fee-for-service (FFS) claims from inpatient and skilled nursing facility (MedPAR), outpatient, and professional services National Claims History files were examined. We also examined Part D (prescription drug) events for patients with the corresponding coverage.

The base cohort consisted of women with a first primary tumor of the breast diagnosed between 2000 and 2017 at age 66 years or older were eligible for inclusion. Previous non-breast primary tumors were not grounds for exclusion from the cohort. Patients diagnosed at any stage were eligible, however, those with T0 tumors were excluded. At least 12 continuous months of FFS Medicare Parts A and B without health maintenance organization coverage prior to diagnosis through at least 3 months after diagnosis was required. Patients with tumors diagnosed at death or who died within 3 months of diagnosis were excluded (Fig. 1). Patients who died in the 3-month post-diagnosis window were excluded under the assumption that individuals who are already very ill or close to death may choose to avoid medical procedures that are unlikely to prolong their life.

From the base cohort (i.e., individuals eligible for diagnostics and known stage outcomes), additional eligibility criteria were applied to select sub-cohorts of patients with sufficient data to perform specific analyses. Inclusion in multilevel analyses required a non-missing group (i.e., facility or area) identifier with a corresponding record in linked datasets (additional details provided in the footnote of Fig. 1). Patients missing data necessary to classify indication or receipt of services for each outcome were excluded from the respective analyses. Only patients with at least one Medicare claim including a provider specialty code were eligible for analyses of oncologist visits. Guideline-concordant locoregional treatment and systemic therapy initiation were examined among sub-cohorts of patients who would have been recommended to receive the respective form of care and were not missing tumor characteristic data necessary to define concordance (Fig. 1). Patients recommended to have locoregional treatment had T1–T3 tumors, were non-metastatic (M0), and were not

missing nodal (N) stage (necessary to determine what locoregional treatment should consist of). Systemic therapy initiation was only examined among patients with Part D Medicare coverage (to determine whether prescription drugs were dispensed) and had known tumor characteristics including subtype, nodal status, and tumor size.

Variables

Definitions of guideline-concordance measures and covariates are detailed in Online Resource 1.

Race and ethnicity—SEER and Medicare enrollment files were used to create a combined race and ethnicity variable based on the best available information, as described in our group's previous work [40, 43]. We utilized this approach to minimize misclassification due to the limitations of each variable including differences in how patient race is determined for the medical record (abstracted into SEER) and limited options for patients to report their own race and ethnicity.

Briefly, we obtained the separately recorded race and ethnicity variables from SEER data as well as the combined race and ethnicity variable from Medicare enrollment files. These data were used to define separate race and ethnicity variables which were then combined into the following categories: AIAN, Asian or Pacific Islander (API), Black, Hispanic White (HW), and non-Hispanic White (NHW). Due to small sample sizes, we were unable to disaggregate AIAN, API, and Black patients by Hispanic ethnicity nor disaggre-gate Asian and Pacific Islander patients. Patients with other or unknown race and ethnicity were excluded (n = 857).

Guideline-concordant care—Outcomes of interest reflected compliance with established quality metrics, including the National Comprehensive Cancer Network (NCCN) clinical practice guidelines (version 4.2021) and American Society of Clinical Oncology and National Quality Forum endorsed measures [44–46]. Specifically, documentation of diagnosis procedures, tumor stage, locoregional treatment, oncology consultation, and systemic therapy initiation were examined. To define guideline-concordant diagnostics, locoregional treatment, and systemic therapy initiation, we first operationalized each service/procedure within each domain using SEER and/or claims data. Diagnostic workup included pathologic confirmation, HR and HER2 status determination, diagnostic mammography, and breast biopsy. Locoregional treatment included axillary staging, surgery, and radiation. Systemic therapy initiation included chemotherapy, hormonal/endocrine therapy, and anti-HER2 agents.

We used both SEER and claims data, where possible, to maximize the sensitivity of each service/procedure variable. That is, to increase the likelihood that, if a treatment was delivered, we would capture it [47, 48]. In cases where both SEER and claims data are used to identify treatment, indication of treatment in either (or both) data source was coded as receiving the treatment. Specifically, a patient was considered to have received a service if they met at least one of the following criteria: SEER variable affirms treatment, at least one procedure claim code, OR two or more diagnosis codes (related to the procedure) at least 30

days but not more than 365 days apart. For detailed operational definitions, including how data sources and variables were combined, refer to Table 1C in Online Resource 1.

We subsequently utilized tumor characteristic data from the SEER registry to determine whether the services/procedures within each domain were consistent with recommendations. Concordance with guidelines was defined by tumor characteristics, including Tumor (T), Node (N), and Metastasis (M) stage, overall stage, or in some cases tumor size or subtype [49, 50]. Guideline-concordant diagnostic workup was defined by M stage. Locoregional treatment concordance was defined by N stage, surgery type, tumor size, and age. Initiation of guideline-recommended systemic therapy was defined by stage, HR and HER2 status, and tumor size.

To identify whether care was guideline-concordant, patients were classified into groups for whom care was indicated, discretionary, or not indicated according to the guidelines based on the relevant tumor characteristics. Patients who received indicated treatment, and those who did not receive treatment that was not indicated, were considered to have guideline-concordant care. For procedures deemed discretionary, care was considered concordant regardless of whether the procedure was delivered or not. For example, mastectomy patients with N1 disease are discretionary for radiation; thus, locoregional treatment for N1 mastectomy patients would be guideline-concordant if the patient received mastectomy with axillary staging, regardless of if radiation was delivered.

Encounters with an oncologist of any type (medical, surgical, or radiation oncologists) during the month before through 3 months after diagnosis were examined. Including pre-diagnosis claims acknowledges imprecision in claim dates used to indicate date of service and leans towards including all potentially relevant cancer-related claims. We examined oncologist visits through 3 months post-diagnosis based on our hypotheses underlying this work that clinical encounters early in the course of care have the potential to shape what happens as patient progresses along the cancer continuum.

Provider specialty was classified according to a validated algorithm using information from FFS claims, Medicare Data on Provider Practice and Specialty, and the American Medical Association (AMA) Physician Masterfile [51, 52]. AMA data were only requested when Medicare data were insufficient to identify oncologists (providers designated as surgeons or with missing or unknown specialty).

Covariates—Patient-level tumor and clinical characteristics included year and age of diagnosis, HR and HER2 status, stage at diagnosis, tumor size, multiple primary tumors, and subsequent malignant tumors. Claims during the 12-month pre-diagnosis period were used to generate validated comorbidity and frailty scores and primary care visits [53–57]. Comorbidity and frailty scores are continuous values reflecting the number of comorbid conditions and impairments that affect activities of daily living or mobility, respectively.

Area-level characteristics were obtained via linkage to outside data sources based on patients' residence at diagnosis. Rural–urban commuting area codes were used to define census tract rurality and provider density ratio was defined as the number of medical

doctors per 100,000 county residents [58–60]. The National Cancer Institute (NCI) social determinants of health dataset provided validated measures of socioeconomic status (SES; Yost index) and racial residential segregation (Local Exposure/Isolation Index) [61–63]. The Local Exposure/Isolation Index reflects the probability that two individuals (Black–White and Hispanic White–NHW) living in the same census tract interact, centered around the expected probability if all race-ethnicities were evenly distributed across the metropolitan statistical area (MSA) [63, 64]. Local Exposure/Isolation Index values below zero indicate the probability of interaction is lower than expected if the MSA were perfectly mixed [63, 64].

Facility-level characteristics included NCI accreditation, Commission on Cancer (CoC) accreditation, medical school affiliation, and breast cancer patient case volume. Facilities were identified from FFS claims during the diagnostic period (3 months before or after diagnosis). Patients treated at multiple facilities were assigned an “index facility,” having the highest designations attained across aforementioned characteristics.

Statistical analysis

Chi-square and ANOVA were used to test the association between race and ethnicity and all patient-, facility-, and area-level covariates, respectively.

We used chi-square tests to examine racial and ethnic differences in proportions with concordant care. Logistic regression models were used to estimate odds ratios (ORs) with corresponding 95% confidence intervals (CIs) by race and ethnicity for each guideline-concordance outcome. NHW patients were used as the reference because it was the largest race and ethnicity group. All analyses were performed among the complete eligible cohort. For outcomes where guideline-concordant care was defined differently based on tumor characteristics, stratified analyses were also performed by the primary defining characteristic (e.g., N or M stage). In unstratified (overall) analyses, the stratification variable was included as a patient-level covariate.

We used the SAS GLIMMIX procedure to estimate ORs with a multilevel structure, using random intercepts to account for clustering of patients within facilities or counties (i.e., level 2-units), respectively. These mixed effects models effectively remove variability in outcomes between units and are interpreted as effects among the patient population independent of treating facility or county of residence. Intraclass correlation coefficients were used to test for clustering (Online Resource 2).

We performed a three-stage model-building process, each building upon the last; Model 1 (unconditional model) included only the outcome and random intercept for level 2-unit, Model 2 with patient-level covariates as fixed effects, and Model 3 included fixed effects for group-level covariates. We used cross-level interaction terms as a means of preliminarily examining whether associations between race and ethnicity and guideline-concordance may be explained by variability in facility- or area-level characteristics. First, we selected which group-level variables were candidates for further examination by assessing the statistical significance of ORs for each outcome by race and ethnicity as well as group-level covariates. Group-level variables significantly associated with both were examined in a final multilevel

model built off of Model 3, which included a multiplicative interaction term between race and ethnicity and each group-level variable, one at a time.

Because marital status and low-income subsidy may mediate the association between guideline-concordance and race and ethnicity, these factors were only included in sensitivity analyses (Online Resource 3). Traditional logistic regression models (not accounting for clustering of subjects by facility or area) are presented in Online Resource 4.

Two-tailed tests with a significance level of 0.05 were utilized for all analyses. All analyses were performed in SAS software version 9.4 (SAS Institute Inc., Cary, NC). Data visualization was performed using R Statistical Software (v7.2.576) via the ggplot2 R package (v2.0.6).

Results

Of the 212,148 women meeting eligibility criteria for inclusion in the diagnostics and known stage analyses, 205,733 were included in facility-level analyses and 145,927 were included in area-level analyses (Fig. 1).

Descriptive statistics for facility and area-level characteristics by race and ethnicity are provided in Table 1. Patient characteristics for the cohort overall and by race and ethnicity are provided in Online Resource 5. Crude proportions for each outcome by race and ethnicity are depicted in Fig. 2. Facility- and area-level clustering was statistically significant for all outcomes except systemic therapy among HR-subtypes (Online Resource 2).

Diagnostics

In the overall cohort, all race and ethnicity groups had significantly lower odds of guideline-concordant diagnostics than NHW women in facility- and area-level analyses (Tables 2 and 3). Among non-metastatic patients, Black women had significantly lower odds of concordant diagnostics than NHW women (OR (95% CI); $OR_{facility}$ 0.80 (0.76–0.84); OR_{area} 0.71 (0.67–0.75)). AIAN women had consistently lower odds of concordant diagnostics; effects were statistically significant among M0 and M1 patients in facility-level models (OR_{M0} 0.73 (0.58–0.91); OR_{M1} 0.46 (0.22–0.99); Table 2). API and HW women had significantly lower odds of concordant diagnostics among M0, but higher odds among unknown metastatic stage patients, compared to NHW.

CoC accreditation and increasing breast cancer case volume were consistently associated with greater odds of guideline-concordant diagnostics (Online Resource 7, Table 1). Increasing area-level provider density was associated with higher odds of guideline-concordant diagnostics (Online Resource 7, Table 2). Among non-metastatic patients, lower SES was associated with consistently lower odds of guideline-concordant diagnostics compared to the highest SES quintile.

Stage known

Black, AIAN and HW women had significantly lower odds of known stage at diagnosis than NHW in both multilevel analyses (Tables 2 and 3). Patients treated at institutions with

CoC accreditation and increasing case volume had significantly higher odds of known stage at diagnosis (Online Resource 7, Table 1). In area-level analyses, odds of known stage at diagnosis were significantly higher with increasing provider density (Online Resource 7, Table 2). Residence in the lowest SES quintile (compared to highest), Black (vs. White) isolation, and rurality were associated with lower odds of known stage at diagnosis; effects were only statistically significant for SES.

Any oncologist

All race and ethnicity groups had significantly lower odds of an oncologist visit than NHW women in both multilevel analyses (Tables 2 and 3). Black and AIAN women had the largest disparity (OR_{Black} 0.75 (0.71–0.79); OR_{AIAN} 0.60 (0.49–0.72); Table 2). All facility characteristics were associated with higher odds of an oncologist visit (Online Resource 7, Table 1). Rurality and low SES were associated with significantly lower odds of an oncologist visit (Online Resource 7, Table 2).

Locoregional treatment

Black and AIAN women had the lowest proportions of eligibility for locoregional treatment analyses and consistently lower odds of concordant treatment than NHW in all analyses (Online Resource 6; Table 1). Differences between Black and NHW women were statistically significant in all area-level analyses and in all facility-level analyses except N2+ patients (Tables 2 and 3). Across racial–ethnic groups, disparities in receipt of guideline-concordant locoregional treatment patients were largest among N1 patients. API women were significantly more likely to receive concordant care, overall and among N0 patients, compared to NHW in facility-level analyses ($OR_{overall}$ 1.12 (1.04–1.20); OR_{N0} 1.11(1.02–1.20)).

Facility characteristics were only associated with increased odds of guideline-concordant locoregional treatment among N2+ patients (Online Resource 7, Table 1). Black isolation was associated with significantly lower odds of concordant treatment overall and among N0 and N2+patients (Online Resource 7, Table 2).

Systemics

Black, AIAN, and NHW women had the lowest proportions of patients eligible for systemic therapy analyses (Online Resource 6). Fewer than 11 AIAN patients were eligible for analyses in some subgroups. AIAN women had the lowest crude proportion treated and consistently had the lowest odds of guideline-concordant systemics across all subgroups in all analyses (Tables 2 and 3). Black women also had lower odds of concordant systemics than NHW in all analyses, with larger disparities among HER2+ patients ($OR_{HR+HER2+}$ 0.78 (0.61–1.01); ORHR−HER2+ 0.67 (0.44–1.02); Table 2). API were significantly more likely to receive guideline-concordant systemic therapy compared to NHW women in the overall cohort ($OR_{facility}$ 1.18 (1.05–1.33); OR_{area} 1.19 (1.04–1.35)).

Patients treated at CoC accredited institutions had higher odds of guideline-concordance in all groups with statistically significant effects in all subgroups except HR+ HER2− (Online Resource 7, Table 1). Increasing facility volume was also associated with increased odds of

guideline-concordant systemic therapy among both HER2− subgroups. Black isolation was associated with lower odds of guideline-concordant systemic therapy with significant effects in the overall cohort and HR+ HER2− subgroup (Online Resource 7, Table 2).

Sensitivity analyses

With additional adjustment for marital status and low-income subsidy, odds of guideline-concordance by race and ethnicity tended to be closer to the null (Online Resource 3). Differences in concordant diagnostics compared were no longer statistically significant for AIAN women (facility-level among M1, area-level overall) or HW women (all facility-level analyses). There were no significant differences in known stage for HW, AIAN (facility analyses), or API (area analyses). API and HW had equivalent odds of oncologist encounter to NHW women in facility-level analyses. Overall, there were no significant differences in systemic therapy for Black women, while HW became significantly more likely to receive concordant systemics compared to NHW. Associations with facility and area characteristics were similar to primary analyses (Table 4).

Discussion

This novel investigation documents consistent disparities in guideline-concordance along the breast cancer care continuum beginning at the time of diagnosis among Black and AIAN patients. While racial–ethnic disparities were observed independent of facility and area characteristics, facility and area were also important predictors of guideline-concordance. CoC accreditation and facility volume were associated with higher odds of guideline-concordant diagnostics, locoregional treatment among complex cases, and systemic therapy. Black residential segregation was consistently associated with lower odds of guideline-concordance, with significant associations for cancer-directed treatment. Residence in socioeconomically disadvantaged and rural areas were associated with lower diagnostic guideline-concordance and oncologist encounters. Our findings demonstrate the importance of place-based factors in racial–ethnic disparities in quality breast cancer care that can be used to identify patients at high risk of sub-standard care provision and help them obtain the high-quality treatment they need and deserve.

Black and AIAN women were less likely to receive the diagnostic workup recommended by practice guidelines than other race and ethnicity groups. As a result, Black and AIAN women were less likely to have sufficient tumor and clinical information necessary to evaluate whether first-line treatment was guideline-concordant. These findings are consistent with evidence of disparate access to high-quality cancer care for Black and AIAN women and evidence that race and SES are associated with missingness of tumor information available in cancer databases [9, 15, 28, 30, 31, 36, 65, 66]. Together, these results demonstrate that by focusing on treatment outcomes alone, we miss earlier points of failure in the clinical experience, and thus miss opportunities to mitigate racial–ethnic disparities in breast cancer care and outcomes. To adequately address inequitable access to high-quality care, interventions must consider the full cancer control spectrum.

Patients treated at CoC accredited and higher volume facilities had higher odds of receiving guideline-concordant care, however, Black, AIAN, and Hispanic White patients were the

least likely to be treated at a CoC accredited facility and non-Hispanic White patients were seen at the highest volume facilities. Our results are consistent with evidence demonstrating improved quality of care and outcomes among breast cancer patients treated at CoC accredited and high-volume facilities [17, 18, 20, 22, 67]. These associations may reflect greater capacity to treat cancer patients or more resources available that facilitate delivery of guideline-concordant care. Alternatively, the availability of specialists, who solely treat cancer and are more likely to be up to date with clinical practice guidelines compared to general surgeons who treat a wide variety of conditions, may explain observed associations. Critically, emerging evidence suggests that access to these high-performing and well-resourced facilities is not equitable across racial and ethnic lines [68, 69]. For example, a 2020 study demonstrated hospitals in areas with high racial residential segregation had lower availability of cancer diagnostic and treatment technologies [68].

Black residential segregation was associated with significantly lower initiation of guideline-recommended treatment while neighborhood SES and rurality were particularly important during the diagnostic phase of care. These patterns reinforce the importance of evaluating quality across the cancer care continuum and considering the diverse needs of medically underserved populations in order to equitably deliver care. Residential segregation has been associated with lower odds of HR status assessment, guideline-concordant locoregional treatment, and chemo-therapy [9–11]. While, to our knowledge, no studies have explicitly examined the role of area SES or rurality in adherence to recommendations for breast cancer diagnostics, lower rates of guideline-concordant treatment have been documented [8, 10, 12, 20, 39, 70–72]. Institutions should assess delivery of care across geography in order to identify underserved areas and quality-improvement evaluations should include area-based assessments to determine whether efforts were equitably delivered. Once identified, institutions can engage with members of these communities to learn about their experiences and better understand the specific barriers residents face.

Strengths and limitations

Our examination of patterns of care among a large, racially and ethnically diverse cohort of older women had several strengths as well as some limitations that warrant consideration. Guideline-concordance outcomes were conceptualized based on widely used practice guidelines and quality metrics and defined in terms of standard practice—receiving treatment as indicated or not receiving treatment if not indicated [46]. However, there were also some limitations to our definitions of concordance. Namely, the guideline-concordant systemic therapy outcome only reflected initiation of appropriate systemics and does not reflect whether the course of treatment as a whole was concordant with guidelines. We sought to examine guideline-concordant care across a larger span of the cancer care continuum, beginning prior to cancer-directed treatment, and thus it was beyond the scope of this work to design a study that could adequately capture the nuances of guideline-recommended systemic therapy. This is an important direction for further research considering established disparities in long-term treatment adherence and completion, such as hormone therapy.

Our analyses included cases diagnosed between 2000 and 2017; yet, concordance measures were primarily based on 2021 NCCN guidelines. Guidelines are updated/revised frequently, and thus our concordance measures may be differentially accurate across years of diagnoses. Although we adjusted all analyses for age at diagnosis, the current trend towards de-escalation of systemic therapy in older women could partially explain non-concordance among older women.

We used validated measures area-level SES and residential segregation which have demonstrated associations with breast cancer incidence and mortality, respectively, and each capture multiple dimensions of complex constructs [62, 64]. We employed multilevel modeling strategies to account for nesting of patients within area of residence and treating facility, which allowed us to account for and quantify variation in outcomes across groups (e.g., across treating facilities). However, the two-level multilevel models limited inference about the effects of social and structural inequality on differences in cancer care; for example, interaction between area residential segregation and individual race and ethnicity were beyond the scope of this work.

We used SEER registry data in combination with insurance claims to minimize the chance of missing services delivered, however procedures not documented in the medical record or not billed to insurance would not be captured. We only analyzed characteristics of one healthcare facility for each patient, however, patients may receive cancer care at many facilities throughout their clinical course. We utilized multiple sources of physician specialty data to distinguish surgical oncologists from general surgeons with high sensitivity, but fellowship-trained breast surgeons, who are not surgical oncologists but specialize in breast cancer treatment, could not be identified.

Due to small sample size and inconsistent collection of detailed racial background data, we were unable to disaggre-gate Asian and Pacific Islander women. Beyond the heterogeneity already present among members of the Asian racial group, Pacific Islanders have particularly distinct patterns of health disparities that are masked when grouped together, often more comparable to that of indigenous patients [73, 74]. AIAN patients were disproportionately excluded from area-level analyses due to residence in non-MSA regions; the patterns of care we observed may not be generalizable to patients residing on reservations and other rural areas. We used multiple sources of race and ethnicity information, including records of IHS medical encounters, to minimize bias from differential accuracy of race and ethnicity variables. Sample sizes for AIAN patients were relatively small, resulting in wide confidence intervals. However, this patient population is often excluded in research; documenting patterns of care among Indigenous peoples, despite small numbers, constitutes an important contribution to the literature.

Conclusions

In this study, we documented disparities in the provision of guideline-concordant care to Black and AIAN women with breast cancer from the diagnostic workup to first-line treatment. Black residential segregation, low area SES, and rurality were associated with less optimal care, while CoC accredited and high-volume facilities provided more guideline-

concordant care. Future research should explicitly examine the role of structural racism—for example, redlining and racial residential segregation's impact on access to healthcare—in the inequitable provision of the standard of breast cancer care across racial–ethnic groups. More sophisticated methods such as stratification and/or mediation models could shed light on the relationship between patients' area of residence and where they seek cancer care and whether intervention at either of these levels would resolve racial disparities without addressing the racist context in which patients live. While referral to CoC accredited or high-volume facilities may increase the likelihood a patient will receive quality breast cancer care, unless this solution is paired with tailored support to help patients overcome the structural barriers to access these facilities, racial–ethnic disparities in quality care and outcomes will persist.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This study used the linked SEER-Medicare database. The interpretation and reporting of these data are the sole responsibility of the authors. The authors acknowledge the efforts of the National Cancer Institute; the Office of Research, Development and Information, CMS; Information Management Services (IMS), Inc.; and the Surveillance, Epidemiology, and End Results (SEER) Program tumor registries in the creation of the SEER-Medicare database. The Healthcare Delivery Research Program and National Cancer Institute created the Social Determinants of Health Data Set used in this work. This data set and documentation were created by Information Management Services, Inc. under US Government contracts HHSN2612 01500003B/75N91020F00001 to facilitate research activities of the NCI-funded Population-based Research to Optimize the Screening Process (PROSPR) consortium. PROSPR grantees, funded under US Government grants U24CA221936, UM1CA221939, UM1CA221940, and UM1CA222035, provided documentation for segregation indices and guidance regarding their creation. The collection of cancer incidence data used in this study was supported by the California Department of Public Health as part of the statewide cancer reporting program mandated by California Health and Safety Code Section 103885; the National Cancer Institute's Surveillance, Epidemiology and End Results Program under contract HHSN261201000140C awarded to the Cancer Prevention Institute of California, contract HHSN261201000035C awarded to the University of Southern California, and contract HHSN261201000034C awarded to the Public Health Institute; and the Centers for Disease Control and Prevention's National Program of Cancer Registries, under agreement # U58DP003862-01 awarded to the California Department of Public Health. The ideas and opinions expressed herein are those of the author(s) and endorsement by the State of California Department of Public Health, the National Cancer Institute, and the Centers for Disease Control and Prevention or their Contractors and Subcontractors is not intended nor should be inferred. The authors acknowledge the efforts of the National Cancer Institute; the Office of Research, Development and Information, CMS; Information Management Services (IMS), Inc.; and the Surveillance, Epidemiology, and End Results (SEER) Program tumor registries in the creation of the SEER-Medicare database.

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Data availability

The SEER-Medicare datasets used to conduct this research are available to researchers upon approval of the research protocol by NCI and SEER. Instructions for obtaining these data are available at https://healthcaredelivery.cancer.gov/seermedicare/obtain/. Linkage with the AMA Physician Masterfile was performed by NCI/SEER contractors. All publically available data sources used in this study are cited in Online Resource 1.

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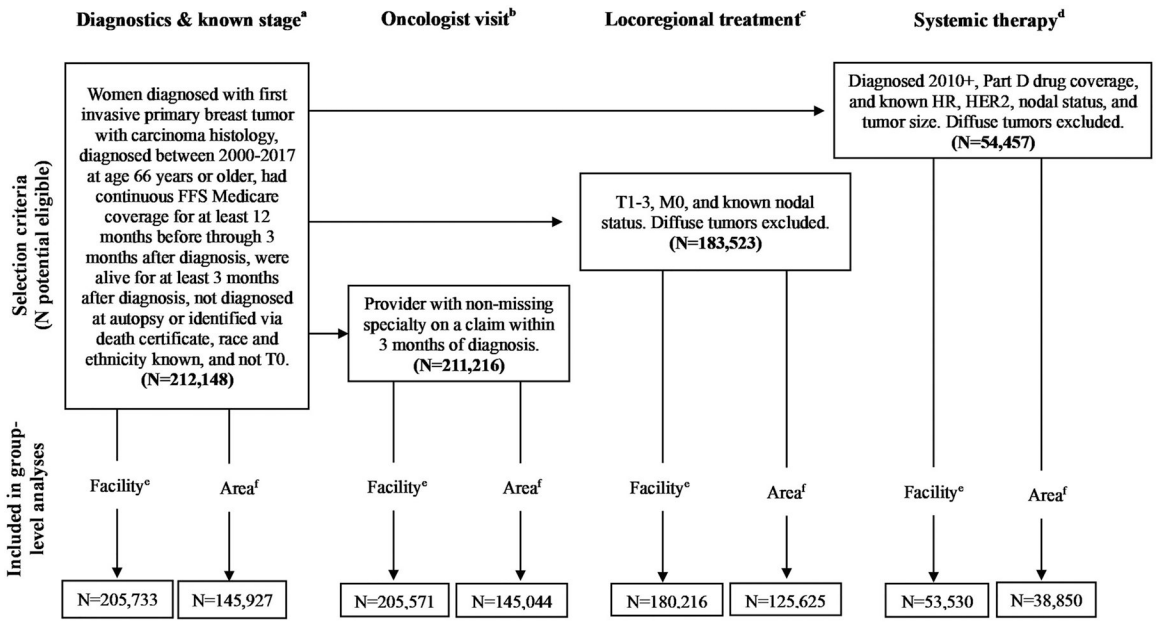

Fig. 1. Flow diagram of cohort selection criteria.

Eligibility criteria imposed for each outcome (horizontal), with number of patients potentially eligible for inclusion in facility-level and area-level analyses, respectively. (Figure created in Microsoft Word). Selection criteria for each outcome (detailed description of figure information): [a]*Diagnostics and staging (base cohort)*: Women diagnosed with first malignant, invasive (ICD-O-3 behavior code = 3) primary breast tumor (site code = C50) diagnosed between 2000 and 2017 at age 66 years or older. Continuous fee-for-service Medicare Part A and B coverage without HMO for at least 12 months prior to diagnosis through at least 3 months after diagnosis was required for inclusion. Patients who died within 3 months of diagnosis or whose breast tumors were diagnosed at autopsy or identified via death certificate were excluded. T0 tumors were excluded. Non-carcinoma histologies, inflammatory carcinoma, Paget disease, and Phyllodes tumors were excluded (ICD-O-3 histology codes 8530, 8540–8543, 9020, and any code greater than 8589). Patients of other or unknown race were excluded. [b]*Oncologist visit*: At least one FFS claim during month before through 3 months after diagnosis that was associated with a provider identification number (i.e., NPI or UPIN) with a non-missing specialty code (either listed on claim, reported in MD-PPAS file, or identified as oncologist in AMA linkage). [c]*Locoregional treatment*: Locoregional treatment concordance was evaluated among patients with T1–3, M0 disease, with known nodal status (positive or negative). Patients with diffuse tumors were excluded. [d]*Systemic treatment*: Diagnosed in 2010 or later (i.e., when HER2 status data were first reported), continuous Part D coverage for at least 3 months after diagnosis, known HR status and HER2 status, known nodal stage, known tumor size, not diffuse tumor. [e]*Criteria for inclusion in facility-level analyses*: Patients included in facility-level analyses had at least one claim for the diagnosis or treatment of breast cancer during the diagnostic period (3 months before through 3 months after diagnosis) which listed a facility identification number with a corresponding Hospital file record. Patients with missing values for facility-level covariates were excluded. [f]*Criteria for inclusion in area-level analyses*: Patients included in area-level analyses had a non-missing census tract boundary number

and matching record in the NCI social determinants of health (SDOH) dataset (and RUCA file and HRSA AHRF). Patients with missing values for area-level covariates were excluded. The NCI SDOH dataset only includes census tracts with a population of at least 200 people; segregation indices were only reported for census tracts located inside Metropolitan Statistical Areas (MSAs) with population of at least 20 people for any of the races used in calculation (Black, White, Hispanic, and non-Hispanic White). *FFS* fee-for-service, *HMO* health maintenance organization, *NPI* national provider identifier, *UPIN* unique physician identification number, *MD-PPAS* Medicare Data on Provider Practice and Specialty, *AMA* American Medical Association, *ICD* International Classification of Diseases, *HR* hormone receptor, *HER2* human epithelial growth factor receptor 2, *NCI* National Cancer Institute, *SDOH* social determinants of health, *MSA* Metropolitan Statistical Area

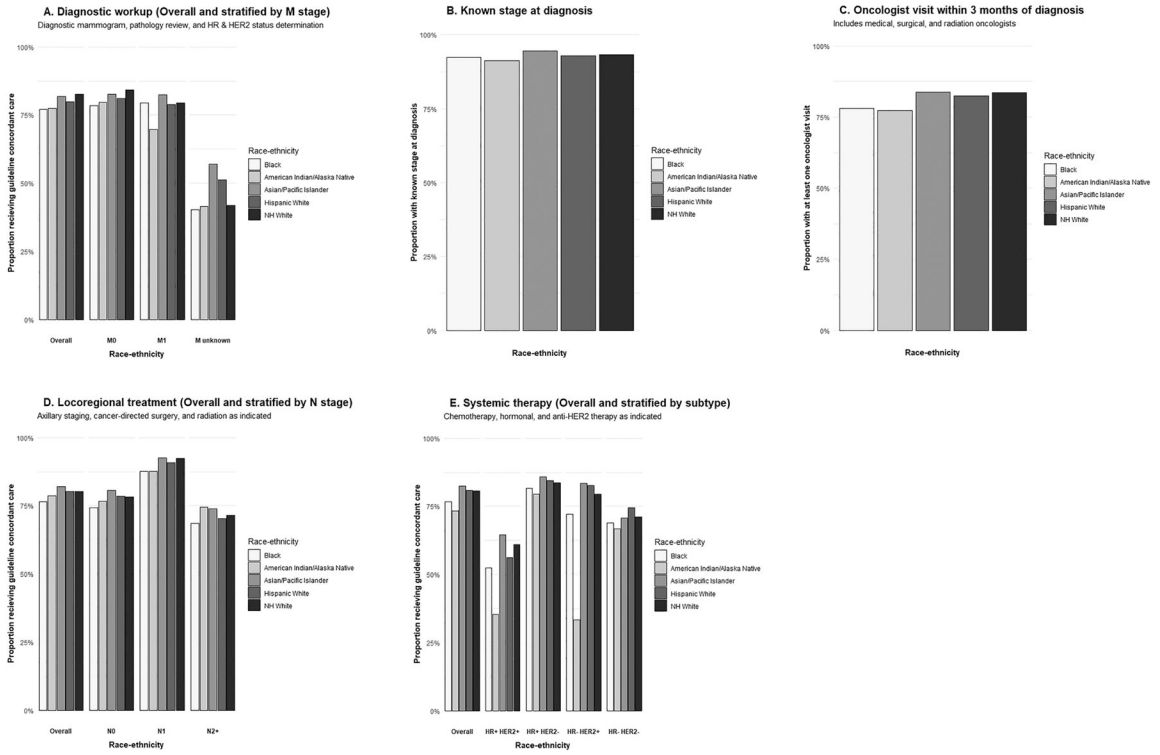

Fig. 2 a–e. Bar charts of receipt of guideline-concordant care outcomes by race and ethnicity

Guideline-concordance outcomes defined according to tumor characteristics are presented for the cohort overall and stratified by the defining characteristic. *p*-values for Chi-Square tests of differences in proportion treated by race and ethnicity are provided in each figure footnote.

(Figures created in R Studio). **a** Overall $p < 0.0001$; M0 $p < 0.0001$; M1 $p = 0.3728$; M unknown $p < 0.0001$. **b** $p < 0.0001$. **c** $p < 0.0001$. **d** Overall $p < 0.0001$; N0 $p < 0.0001$; N1 $p = 0.3728$; N2+ $p = 0.1664$. **e** Overall $p < 0.0001$; HR+ HER2+ $p = 0.0013$; HR+ HER2− $p = 0.0008$; HR− HER2+ $p = 0.0009$; HR− HER2− $p = 0.4561$

Table 1.
Race and ethnicity and group-level characteristics.

N (Column %).

N (%)	Overall		Black N=16,247	American Indian/ Alaska Native N=849	Asian/ Pacific Islander N=8,636	Hispanic White N=9,914	Non-Hispanic White N=176,502
Facility-level covariates							
Eligible for facility-level analyses	205,733 (97.0)	**Eligible**	15,661 (96.4)	810 (95.4)	8,268 (95.7)	9,580 (96.6)	171,414 (97.1)
National Cancer Institute Affiliation	14,906 (7.3)	**Affiliated** (vs. not affiliated)	1,322 (8.4)	38 (4.7)	1,167 (14.1)	738 (7.7)	11,641 (6.8)
Commission on Cancer Accreditation	125,695 (61.1)	**Accredited** (vs. not accredited)	9,151 (58.4)	386 (47.7)	5,049 (61.1)	5,230 (54.6)	105,879 (61.8)
Medical school affiliation/teaching hospital	125,713 (61.1)	**Affiliated** (vs. not affiliated)	11,160 (71.3)	393 (48.5)	5,729 (69.3)	6,014 (62.8)	102,417 (59.8)
Breast cancer case volume (3 year moving average)	50.6 (47.5)	**Mean (SD)**	46.67 (41.3)	30.37 (32.0)	45.73 (46.6)	42.44 (44.6)	51.7 (48.2)
Area-level covariates							
Eligible for area-level analyses	145,927 (68.8)	**Eligible**	11,804 (72.7)	427 (50.3)	6,352 (73.6)	7,519 (75.8)	119,825 (67.9)
Provider density (per 100,000 population)	318.2 (160.2)	**Mean (SD)**	340.64 (168.4)	287.08 (144.4)	359.44 (142.5)	301.44 (140)	314.97 (161)
Rural	14,974 (10.3)	**Rural** (vs. urban)	1,007 (8.5)	102 (23.9)	270 (4.3)	651 (8.7)	12,944 (10.8)
Yost SES quintile	18,717 (12.8)	**Q1**	4,353 (36.9)	88 (20.6)	471 (7.4)	1,621 (21.6)	12,184 (10.2)
	22,386 (15.3)	**Q2**	2,484 (21.0)	103 (24.1)	695 (10.9)	1,449 (19.3)	17,655 (14.7)
	26,219 (18.0)	**Q3**	1,930 (16.4)	78 (18.3)	1,041 (16.4)	1,448 (19.3)	21,722 (18.1)
	34,110 (23.4)	**Q4**	1,800 (15.3)	92 (21.6)	1,672 (26.3)	1,475 (19.6)	29,071 (24.3)
	44,495 (30.5)	**Q5**	1,237 (10.5)	66 (15.5)	2,473 (38.9)	1,526 (20.3)	39,193 (32.7)
Black (vs. White) Residential Segregation (Lex/IS)	−0.31 (0.4)	**Mean (SD)**	−0.14 (0.4)	−0.15 (0.4)	−0.33 (0.5)	−0.27 (0.4)	−0.33 (0.5)
Hispanic (vs. non-Hispanic White) Residential Segregation (Lex/IS)	−0.22 (0.4)	**Mean (SD)**	−0.6 (0.7)	−0.14 (0.4)	−0.32 (0.4)	−0.2 (0.4)	−0.18 (0.3)

Abbreviations: Q=Quintile, NCI=National Cancer Institute, SDOH=Social Determinants of Health, SES= Socioeconomic Status, Lex/IS=Local Exposure and Isolation Index.

Chi-square and ANOVA tests of association by race and ethnicity for each covariate (categorical and continuous, respectively) were all statistically significant with p<0.0001. Yost socioeconomic status (SES) quintile, weighted to US population correspond to ACS survey year closest to, but before, patients' diagnosis date, from SEER and SDOH. Provider density per 100,000 population uses estimates for total population numbers per county from US census or ACS estimates closest to year of diagnosis. Local Exposure and Isolation Indices (Lex/Is) are measures of racial

residential segregation. Breast cancer case volume (per facility) calculated as 3-year moving average number of breast cancer patients (in this study population); value corresponds to 3 year moving average for patients' year of diagnosis.

Table 2.

Odds of Guideline-Concordance by Race and Ethnicity: Facility Multilevel Models Adjusted for Patient-Level Covariates.

Guideline-Concordant:	Stratification	N	Black (vs. NHW)	American Indian/ Alaska Native (vs. NHW)	Asian/Pacific Islander (vs. NHW)	Hispanic White (vs. NHW)
Diagnostics	Overall	205,733	**0.83 (0.79–0.88)**	**0.66 (0.54–0.81)**	**0.84 (0.78–0.91)**	**0.94 (0.88–0.99)**
	M0	192,833	**0.8 (0.76–0.84)**	**0.73 (0.58–0.91)**	**0.86 (0.79–0.93)**	**0.93 (0.87–0.99)**
	M1	8,390	1.03 (0.84–1.26)	**0.46 (0.22–0.99)**	0.94 (0.66–1.33)	0.83 (0.63–1.09)
	M unknown	4,510	0.89 (0.7–1.14)	0.61 (0.24–1.56)	**1.73 (1.15–2.59)**	1.28 (0.94–1.75)
Stage known		205,733	**0.87 (0.8–0.94)**	**0.63 (0.47–0.85)**	1.03 (0.9–1.17)	**0.83 (0.76–0.92)**
Oncologist visit		205,571	**0.75 (0.71–0.79)**	**0.6 (0.49–0.72)**	**0.9 (0.83–0.97)**	**0.87 (0.82–0.93)**
Locoregional	Overall	180,216	**0.8 (0.76–0.84)**	0.84 (0.68–1.03)	**1.12 (1.04–1.2)**	0.99 (0.93–1.05)
	N0	139,629	**0.82 (0.77–0.86)**	0.88 (0.69–1.1)	**1.11 (1.02–1.2)**	0.99 (0.92–1.06)
	N1	29,996	**0.62 (0.54–0.72)**	0.57 (0.31–1.03)	1.07 (0.82–1.4)	**0.76 (0.62–0.93)**
	N2+	10,591	0.9 (0.77–1.05)	0.89 (0.44–1.77)	1.02 (0.8–1.32)	0.88 (0.72–1.07)
Systemics	Overall	53,530	**0.9 (0.83–0.98)**	**0.66 (0.48–0.91)**	**1.18 (1.05–1.33)**	1.1 (0.99–1.22)
	HR+ HER2+	4,308	0.78 (0.61–1.01)	**0.34 * (0.12–0.98)**	1.18 (0.87–1.6)	0.92 (0.7–1.2)
	HR+ HER2−	42,731	0.9 (0.8–1.0)	0.77 ** (0.52–1.14)	**1.23 (1.07–1.41)**	1.1 (0.97–1.25)
	HR− HER2+ †	1,641	0.67 (0.44–1.02)	**0.07 * (0.01–0.3)**	1.04 (0.58–1.87)	1.46 (0.79–2.72)
	HR− HER2−	4,850	0.91 (0.73–1.14)	0.55 (0.2–1.53)	0.94 (0.65–1.34)	1.1 (0.78–1.54)

Abbreviations: NHW=non-Hispanic White, M=metastases (stage), N=nodal status (stage), HR=Hormone Receptor, HER2=Human Epithelial Growth Factor Receptor 2

Odds ratios (ORs) generated from multilevel models accounting for clustering/nesting within facilities.

† Indicates clustering was not statistically significant. Bolded text reflect statistically significant odds ratios at 0.05 level.

* Denotes fewer than 11 patients per race and ethnicity group in one or both levels of the outcome.

** Denotes fewer than 11 patients per race and ethnicity group were eligible for analysis/outcome (i.e., across both levels of the outcome).

Patient-level covariates adjusted for in all analyses were: age at diagnosis, year of diagnosis, frailty score, comorbidity score, previous non-breast malignant primary tumor, and baseline primary care visits. For treatment outcomes, analyses were also adjusted for subsequent tumors diagnosed during treatment period and HR status. Systemic therapy analyses were also adjusted for stage at diagnosis. For each outcome where stratification was performed, the overall analysis was adjusted for the stratification variable (e.g., diagnostics overall was adjusted for M status).

Table 3.

Odds of Guideline-Concordance by Race and Ethnicity: Area Multilevel Models Adjusted for Patient-Level Covariates.

Guideline-Concordant:	Stratification	N	Black (vs. NHW)	American Indian/ Alaska Native (vs. NHW)	Asian/Pacific Islander (vs. NHW)	Hispanic White (vs. NHW)
Diagnostics	**Overall**	145,927	**0.74 (0.7–0.78)**	**0.77 (0.59–0.99)**	**0.76 (0.7–0.82)**	**0.87 (0.81–0.92)**
	M0	134,845	**0.71 (0.67–0.75)**	0.8 (0.6–1.06)	**0.72 (0.67–0.78)**	**0.83 (0.78–0.89)**
	M1	6,441	0.98 (0.79–1.2)	0.54 * (0.21–1.4)	1.42 (0.95–2.14)	0.95 (0.71–1.26)
	M unknown	4,641	0.95 (0.76–1.19)	0.53 * (0.2–1.42)	**1.46 (1.03–2.07)**	**1.46 (1.1–1.94)**
Stage known		145,927	**0.81 (0.75–0.87)**	**0.49 (0.35–0.67)**	**0.84 (0.75–0.95)**	**0.88 (0.8–0.97)**
Oncologist visit		145,044	**0.69 (0.65–0.72)**	**0.70 (0.54–0.9)**	**0.83 (0.77–0.9)**	**0.81 (0.76–0.86)**
Locoregional	**Overall**	125,625	**0.79 (0.75–0.83)**	0.81 (0.62–1.06)	1.04 (0.96–1.12)	0.98 (0.92–1.05)
	N0	97,622	**0.82 (0.77–0.87)**	0.84 (0.62–1.13)	1.00 (0.92–1.09)	0.96 (0.9–1.04)
	N1	20,823	**0.62 (0.53–0.73)**	0.62 * (0.29–1.32)	0.93 (0.71–1.21)	**0.75 (0.61–0.93)**
	N2+	7,180	**0.81 (0.68–0.97)**	0.86 * (0.3–2.49)	1.05 (0.79–1.4)	0.85 (0.67–1.06)
Systemics	**Overall**	38,850	**0.90 (0.82–0.99)**	0.71 (0.47–1.08)	**1.19 (1.04–1.35)**	1.11 (0.99–1.24)
	HR+ HER2+	3,109	0.77 (0.57–1.02)	0.48 * (0.14–1.66)	1.25 (0.88–1.76)	0.92 (0.68–1.23)
	HR+ HER2−	31,010	0.92 (0.82–1.04)	0.78 (0.48–1.27)	1.15 (0.99–1.34)	1.10 (0.96–1.27)
	HR− HER2+ †	1,195	0.74 (0.45–1.2)	0.29 ** (0.03–3.21)	1.17 (0.62–2.21)	1.44 (0.73–2.83)
	HR− HER2− †	3,536	0.94 (0.73–1.21)	0.29 * (0.07–1.19)	0.84 (0.56–1.26)	0.95 (0.66–1.36)

Abbreviations: NHW=non-Hispanic White, M=metastases (stage), N=nodal status (stage), HR=Hormone Receptor, HER2=Human Epithelial Growth Factor Receptor 2

Odds ratios (ORs) generated from multilevel models accounting for clustering/nesting within counties.

† Indicates clustering was not statistically significant. Bolded text reflects statistically significant odds ratios at 0.05 level.

* Denotes fewer than 11 patients per race and ethnicity group in one or both levels of the outcome.

** Denotes fewer than 11 patients per race and ethnicity group were eligible for analysis/outcome (i.e., across both levels of the outcome).
Patient-level covariates adjusted for in all analyses were: age at diagnosis, year of diagnosis, frailty score, comorbidity score, previous non-breast malignant primary tumor, and baseline primary care visits. For treatment outcomes, analyses were also adjusted for subsequent tumors diagnosed during treatment period and HR status. Systemic therapy analyses were also adjusted for stage at diagnosis. For each outcome where stratification was performed, the overall analysis was adjusted for the stratification variable (e.g., diagnostics overall was adjusted for M status).

Table 4.

Cross-level Interactions: Patient Race and Ethnicity by Facility- and Group-level Characteristics.

Guideline-Concordant:	Interaction term		Black	American Indian/ Alaska Native	Asian/ Pacific Islander	Hispanic White
Facility-level characteristics						
Diagnostics (overall)	CoC		1.07	**1.59** *	1.09	1.10
	Case volume *		**1.002** *	1.002	1.001	**1.003** *
Stage known	**NCI** *		**1.66** *	2.91	**1.65** *	1.43
	CoC		0.88	1.27	1.23	0.99
	Case volume		1.00	1.003	1.003	0.999
Oncologist visit	NCI		0.82	1.09	0.86	1.24
	CoC		0.92	1.47	0.98	0.98
	Med school *		**0.89** *	1.24	0.90	**0.84** *
	Case volume		0.999	1.00	**0.998** *	0.999
Locoregional treatment (Overall)	NCI		0.94	0.77	0.93	0.94
	CoC		1.02	**1.53** *	1.06	0.99
	Med school		0.99	1.01	1.02	0.98
	Case volume		1.00	0.995	0.999	1.00
Systemic therapy initiation (Overall)	CoC		1.19	0.79	1.16	0.99
	Case volume		1.00	0.99	1.00	0.999
Area-level characteristics						
Diagnostics (overall)	**Provider density** *		1.00	0.999	1.00	**1.001** *
	Rural		**1.19** *	0.87	1.46	0.94
	Yost SES * (vs. Q5)	Q1	1.10	1.89	**0.77** *	**0.78** *
		Q2	1.02	1.49	**0.71** *	**0.74** *
		Q3	0.97	2.39	1.06	**0.71** *
		Q4	1.03	1.44	**0.79** *	**0.76** *
Stage known	Provider density		1.00	0.999	0.999	1.00
	Yost SES (vs. Q5)	Q1	1.09	0.85	**0.56** *	**0.72** *
		Q2	1.12	0.85	**0.63** *	0.87
		Q3	0.97	2.32	0.76	0.79
		Q4	1.17	0.92	**0.70** *	0.85
Oncologist visit	Rural		1.08	0.74	0.85	1.12
	Yost SES (vs. Q5)	Q1	0.95	0.44	0.83	0.90
		Q2	0.88	0.43	**0.78** *	0.82
		Q3	0.92	0.57	0.99	0.88
		Q4	0.91	0.69	**0.83** *	0.93

Guideline-Concordant:	Interaction term		Black	American Indian/ Alaska Native	Asian/ Pacific Islander	Hispanic White
Locoregional treatment (Overall)	Yost SES (vs. Q5)	Q1	0.999	**2.81** *	1.02	0.91
		Q2	1.05	1.55	0.84	1.02
		Q3	0.97	1.66	0.91	1.02
		Q4	1.01	1.58	0.89	**1.29** *
	Black Residential Segregation (Lex/IS) *		0.97	1.49	**0.80** *	0.97
Systemic therapy initiation (Overall)	Black Residential Segregation (Lex/IS)		1.12	1.61	1.10	0.87

* Indicates an effect was statistically significant at the 0.05 alpha level. Significance in the interaction term column indicates a statistically significant Type 3 Tests of Fixed Effect of the overall product term for that characteristic with race and ethnicity. Results presented in this table were generated from adding a product interaction term (race and ethnicity*characteristic) to fully adjusted model 3. Model 3 adjusts for patient-level covariates and group-level covariates pertaining to the related level of analysis.

Patient-level covariates included: age at diagnosis, year of diagnosis, frailty score, comorbidity score, previous non-breast malignant primary tumor, and baseline primary care visits. For treatment outcomes, analyses were also adjusted for subsequent tumors diagnosed during treatment period and HR status. Systemic therapy analyses were also adjusted for stage at diagnosis. All outcomes were analyzed overall, thus the stratification variable (e.g., diagnostics overall was adjusted for M status) was also adjusted for in patient-level covariates.