HHS Public Access

Author manuscript

Ann Surg. Author manuscript; available in PMC 2024 July 07.

Published in final edited form as:

Ann Surg. 2024 June 01; 279(6): 1054–1061. doi:10.1097/SLA.0000000000006156.

Residential Redlining, Neighborhood Trajectory, and Equity of Breast and Colorectal Cancer Care

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INTRODUCTION

Inequity in access to, receipt of, and outcomes from cancer care delivery have been well documented, with people of color, uninsured, and poor populations having particularly deleterious results.[1–6] These inequities are driven through multiple levels of oppression and racism, including structural, interpersonal, and intrapersonal factors.[7] Significant gaps in knowledge remain regarding how historical, sociopolitical, and structural factors influence current inequities in cancer care delivery.[8,9] Residential redlining (the discriminatory practice of refusing to provide financial services to consumers who live in areas with a significant number of people of color and low income individuals) provides a model to understand how historical policies influence current equity of cancer care in the United States. A well-documented example of structural racism, residential redlining relegated minoritized populations into communities with limited access to vital services and economic resources, poorer environmental conditions, and ultimately subverted generational wealth.[10–12] Thus in addition to income inequalities, redlining is a primary contributor to current wealth inequality that in turn influences access to and receipt of optimal health care.[13]

Redlining originated with The Home Owners' Loan Act of 1933 which sought to provide government-backed mortgages to support American home owners during the Great

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Author Contributions The contributions of authors can be found in Supplemental Digital Content 6.

Conflict of Interest: Authors report no conflicts of interest related to this study.

Depression.[14] The Home Owners' Loan Corporation (HOLC) was formed and created maps in hundreds of cities across the US, ranking neighborhoods based on perceived loan worthiness.[10] Redlined areas were neighborhoods considered the highest risk of loan default. One key factor in determining neighborhood risk was the presence of "undesirable" inhabitants, Black residents, foreign-born, Jewish and Irish residents. Thus, while multiple factors could contribute to neighborhoods being redlined, all predominantly Black neighborhoods were de facto graded as being hazardous. The legacy of redlining lingers, influencing both racial and socioeconomic makeup of communities in present day, including average credit scores, probability of living in high-poverty, and probability of upward mobility.[10–14] However, these historic policies did not alone dictate current structures but strengthened an inequitable foundation for decades of banking, real estate, city-planning, and other policies to ignore, improve, or double-down on the legacy of redlining.[15–17] Recent efforts to improve historically oppressed communities have revitalized some areas but have also further marginalized minoritized individuals in the community.[14] These dynamic aspects of communities, each shaped by its past, can be overlooked in studies evaluating or simply controlling for historic characteristics or current socioeconomic conditions in isolation. The implications are especially significant for neighborhoods that may have seen investment or improvement in socioeconomic measures as a whole, but do so via isolation or segregation of previous residents. Gentrification is this process of neighborhood demographic or socioeconomic changes that displace or further segregate people of color, of lower socioeconomic status, or both. While studies have shown an association between historical redlining and adverse health outcomes including for cancer, the influence of neighborhood trajectories on cancer care is less well appreciated.[18–21]

The objective of this study was to evaluate how changes in neighborhood conditions from historic redlining classification to current socioeconomic status ("Neighborhood Trajectory") influence timely diagnosis with and receipt of cancer-directed surgery (CDS) for breast and colorectal cancer. These cancers were selected as they are common, treatable if caught early, have well established screening options, and each have well-documented of inequities in both presentation and management.[1–7] We hypothesize that historically redlined areas will be associated with later stage cancer at time of diagnosis and decreased receipt of surgery, largely mediated through current socioeconomic conditions. Historically disadvantaged neighborhoods that have improved socioeconomic status (i.e. "gentrified") may show overall improved outcomes but may also have more significant racial inequity in care.

METHODS

Assigning HOLC Grades and Area Deprivation Index to Block Groups

Our study area was the seven cities in Indiana included in the HOLC program: Evansville, Ft. Wayne, Gary, Indianapolis, Muncie, South Bend and Terre Haute. We obtained digitized HOLC neighborhoods from Mapping Inequality: Redlining in New Deal America Project from the University of Richmond and intersected them with the 2010 U.S. Census block group polygons for the state of Indiana.[22] If the block group had less than 50% of its area

graded under the HOLC program, we assigned it “No Grade” and it was not considered part of the study area. For the remaining areas, we multiplied the proportion of the graded area in each block group by 1 for grade A-Best, 2 for grade B-Still Desirable, 3 for grade C-Definitely Declining and 4 for grade D-Hazardous. Areas graded as “D-Hazardous” were mapped with red shades on original HOLC maps and are those we refer to as “historically redlined.” We then summed those values and rounded them to the nearest integer to get an equivalent HOLC grade for each block group.

In addition to the HOLC grade, each block group was also assigned a state level Area Deprivation Index (ADI) which ranks block groups from 1 – Least Deprived to 10- Most Deprived based on a composite of 17 unique characteristics from the 2015 US Census American Community Survey, including area-level measures of education, employment, housing-quality, and poverty. [23,24] We selected ADI from other measures of social drivers of health as it captures a range of socioeconomic factors, especially around housing quality, and has been repeatedly shown to be associated with variation in access to, receipt of, and outcomes from cancer care.[24] The examination of ADI decile distribution among the block groups led to collapsing the ADI deciles into four ADI categories: 1–3 Least Deprived, 4–6 Less Deprived, 7–8 More Deprived and 9–10 Most Deprived. These categories were selected based on prior studies showing greater magnitude in the association between ADI and outcomes for areas with higher deprivation.[18]

To evaluate changes in neighborhoods from historic HOLC grades to present degree of deprivation, we further aggregated block groups into 4 “Neighborhood Trajectories” that describe their path from the HOLC grade to the current ADI. The Neighborhood Trajectories were grouped as “Advantage Stable” for block groups with HOLC grade A and B and ADI 1–6; “Advantage Reduced” for HOLC grade A and B and ADI 7–10; “Disadvantage Reduced” for HOLC grade C and D and ADI 1–6; and “Disadvantage Stable” for HOLC grade C and D and ADI 7–10 (Supplemental Digital Content 1).

Data Source, Study Period, Cancer Diagnosis, Study Cohort, Outcomes

The Indiana State Cancer Registry (ISCR) provided cancer data for patients with incident colorectal and breast cancer. The ISCR is certified by the North American Association of Central Cancer Registries (NAACCR) and follows standardized codes and definitions for all cancers diagnosed and/or treated in Indiana.[25] The study period of interest was 2010–2015 and, to stay most temporally proximate to this clinical data, we used the 2015 ADI which was derived from the 2011–2015 American Community Survey. Patients residing in the seven Indiana cities were included (Figure 1). We included all adults 18 years or older with an International Classification of Diseases for Oncology, third edition (ICD-O-3) diagnosis code for cancer of the colon, rectum, or breast (Supplemental Digital Content 2). Male breast cancers, patients with unknown stage or those with other or unknown race were excluded from the study cohort. Race and ethnicity was reported by ISCR at time of diagnosis noting that race and ethnicity may differ by reporting facility. After completion of the study cohort derivation, the patient data from the ISCR was merged with the HOLC, ADI and Neighborhood Trajectory classifications based on the block group identifiers

provided by the ISCR (Figure 2). The resulting analytic file's unit of analysis was at the individual patient level with neighborhood level characteristics at the block group.

The two primary outcome measures were late-stage presentation at the time of diagnosis and receipt of cancer-directed surgery (CDS). Stage at diagnosis was dichotomized as late (III, IV) versus early (0, I, II) and was derived from AJCC stage 7th edition stage groups (Supplemental Digital Content 2).[26] Receipt of CDS was defined as the presence or absence of the most definitive surgical procedure to the primary site (Supplemental Digital Content 3).[27] For analyses of receipt of CDS, the cohort was limited to patients with Stage 0-III cancer.

Statistical Analysis

Frequency distributions (N; %) are reported for patient and block group characteristics by Neighborhood Trajectories. To preserve confidentiality, statistics were not displayed if there were fewer than 11 cancer cases in at least one patient characteristic group. Patient characteristics included age at diagnosis (categorized into groups: <55, 55–74, 75+ years old), sex, race/ethnicity (non-Hispanic (NH) White, NH Black and Hispanic – any race), diagnosis year, city of patient residence, and cancer type. Race was use as a sociopolitical construct and to control for different levels of racism.[7] As both residential redlining and current neighborhood compositions are manifestations of structural racism, primary models did not include race/ethnicity as a confounding factor. Sensitivity models including race and ethnicity did not significantly alter results. Block group characteristics consisted of HOLC grade, Neighborhood Trajectory and ADI group.

Poisson regression models with a robust error variance estimated the relative risks (RR) and the corresponding 95% confidence intervals (CI) for the block group characteristics' impact on cancer stage and receipt of CDS.[28,29] Results for late stage and CDS models are reported overall and separately by cancer type. Models were adjusted for patient characteristics listed above and CDS models were restricted to a non-metastatic cancer population. Sensitivity analysis stratified analysis by patient race/ethnicity to evaluate differential influence of Neighborhood Trajectory for NH White and NH Black patients. Initial unadjusted models suggested a possible interaction between late stage, patient race/ethnicity and Neighborhood Trajectory and CDS, patient race/ethnicity and Neighborhood Trajectory. Therefore, stratification of models by Neighborhood Trajectory enabled examination of differences among race/ethnicity groups for late-stage cancer and receipt of CDS. Analyses were performed in SAS 9.4 and STATA 15.[30,31]

RESULTS

The seven cities in the study area contained 1,557 block groups, of which 1,130 overlapped with HOLC neighborhoods. Of these block groups 363 had less than 50% of their area overlapped by a HOLC neighborhood and were excluded from the study area. The remaining 767 block groups were assigned HOLC grades, 17 of these block groups had no patients in our study cohort and an additional 4 block groups did not have an ADI due to suppression criteria. Of the 746 block groups with ADI, the largest of the Neighborhood Trajectory groups (combination of HOLC grade and ADI) was Disadvantage

Stable with 493 block groups followed by Disadvantage Reduced with 112. Advantaged Stable contained 83 block groups while Advantage Reduced was the trajectory with the smallest number of block groups at 58. Breakdown of patient residence by HOLC grade, Neighborhood Trajectory, and ADI are demonstrated in Figure 2.

Clinical Cohort

We initially identified 5,142 patients that resided in one of seven Indiana cities from January 1, 2010, to December 31, 2015. After meeting all inclusion criteria, the final cohort included 4,862 patients with colorectal (n = 1,478) or breast (n = 3,384) cancer (Table 1). The cohort's mean age at diagnosis and standard deviation (SD) was 62.7 (12.8) years and most of the cohort were females (84.9%) and of NH White race/ethnicity (62.0%). More than half of cohort resided in Indianapolis (53.3%), 27.1% were diagnosed with late stage (III, IV) and 86.9% received CDS. Patients classified with a Neighborhood Trajectory as Disadvantage Stable comprised 60.5% of the cohort followed by Disadvantage Reduced (21.8%), Advantage Stable (11.6%) and Advantage Reduced (6.2%). Compared to the Advantage Stable neighborhoods, those residing in Disadvantage Stable neighborhoods were more likely to be of NH Black race/ethnicity, more likely to be diagnosed with late stage, and were less likely to receive CDS.

Additional distributions of cancer patient and block group characteristics are reported by cancer type (Supplemental Digital Content 4) and by stage and receipt of CDS (Supplemental Digital Content 5). Historically redlined neighborhoods (Grade D - Hazardous) resulted in increased risk of late-stage cancer among those diagnosed with colorectal cancer and breast cancer ($RR_{D-Hazardous}$ = 1.37, 95% CI = 1.02 – 1.83; $RR_{D-Hazardous}$ = 1.90, 95% CI = 1.28 – 2.81, respectively; Table 2). Model results found the Disadvantage Stable trajectory was associated with increased RR for late-stage diagnosis for colorectal and breast cancer ($RR_{Disadvantage\ Stable}$ = 1.30, 95% CI = 1.05 – 1.59; $RR_{Disadvantage\ Stable}$ = 1.41, 95% CI = 1.09 – 1.83, respectively; Table 2). After controlling for stage at presentation and other confounding factors, there was no overall association between Neighborhood Trajectory and receipt of CDS among non-metastatic breast or colorectal cancer patients (Table 2). Sensitivity analyses including patient race/ethnicity in models did not change results.

When stratifying to assess for different impact of Neighborhood Trajectory by patient race/ethnicity, Disadvantage Stable was associated with later stage diagnosis for both NH White and NH Black patients ($RR_{Disadvantage\ Stable}$ = 1.26, 95% CI = 1.04 – 1.52; $RR_{Disadvantage\ Stable}$ = 1.64, 95% CI = 1.04 – 2.59, respectively; Table 3). Similar to overall models, there was no association between Neighborhood Trajectory and receipt of CDS when stratifying by race/ethnicity. When stratifying analyses by Neighborhood Trajectory to assess for racial inequity within different Neighborhood Trajectories, we found that there was no statistically significant racial inequity in late-stage cancer within any of the four trajectories, (Table 4). Examining CDS, however, NH Black patients had significantly lower receipt of surgery compared to NH White patients only in Disadvantage Reduced neighborhoods ($RR_{Disadvantage\ Reduced}$ = 0.92, 95% CI 0.86 – 0.99; Table 4).

DISCUSSION

Structural racism and oppression have been recognized but incompletely dissected as contributors to ongoing inequity in cancer care delivery.[32] In this study evaluating the influence of historic redlining and subsequent Neighborhood Trajectory, we report that patient residence in neighborhoods with persistent disadvantage are associated with later stage cancer at the time of diagnosis. This relationship was largely consistent for both NH White and NH Black patients with colorectal and breast cancer, although of greater magnitude for NH Black patients. While there was no overall association between Neighborhood Trajectory and receipt of CDS, we found racial inequity in receipt of CDS within Disadvantage Reduced ("gentrified") neighborhoods, with NH Black patients having significantly lower receipt of CDS compared to NH White patients.

These data build on a growing body of evidence confirming the relationship between where one lives and the quality of cancer care delivery.[33–36] Importantly, these neighborhoods conditions do not arise in isolation but are the results of past and present policies, systems, and practices, including historic redlining and more recent gentrification.[37] Redlining has been shown to be associated with many of the known social determinants of cancer care disparities, including adverse environmental conditions, employment, and wealth.[38] The spatial factors contributing to inequities in cancer care include socioeconomic inequality and racial/ethnic segregation, each independently associated with decreased access to and receipt of care for number of medical and surgical conditions.[39,40] Measures of local area environment, like the Area Deprivation Index, are increasingly identified as contributors to disparate incidence of cancer, stage of cancer diagnoses, receipt of stage-appropriate care, and overall outcomes.[41–43] The findings of the present study are consistent with prior work with historically redlined areas having a significantly worse stage at the time of diagnosis. Our work did not show an overall association with decreased receipt of CDS for patients in historically redlined communities after controlling for stage at diagnosis, suggesting that gaps in early diagnosis play a key role in known inequities in long-term outcomes.

Our results build on prior studies in important ways. First, our categorization of neighborhoods using census block groups rather than tracts allows for a more precise approximation of historic HOLC and current census boundaries. Additionally, the use of Neighborhood Trajectory provides a novel and dynamic evaluation not only of neighborhoods whose disadvantage/advantage was stable (65% and 10% respectively) over the past 70 years but also those with reduced disadvantage or advantage. Our evaluation of CDS in Disadvantage Reduced neighborhoods suggested a potentially dichotomous impact of development via gentrification. Historically poor (and disproportionately Black) neighborhoods that have Disadvantage Reduced over time may have benefits at reducing overall gaps in care, especially for timely diagnosis with screening-sensitive malignancies of the colon, rectum, and breast. None of our unadjusted or adjusted models found a significant difference between stage at diagnosis or receipt of CDS between patients in Disadvantage Reduced and Advantage Stable communities. Improvement in the socioeconomic environment may mitigate gaps in timely diagnosis or receipt of CDS, but our results also suggest that this improvement may not be experienced equally across populations. In particular, Black patients had statistically significant lower likelihood of

receiving CDS in Disadvantage Reduced neighborhoods alone, even after controlling for stage at presentation. These data suggest that while overall measures of access to and receipt of surgery in Disadvantage Reduced communities may improve, racial inequity persists or may be introduced. The systems, structures, and dynamics created during gentrification may marginalize and oppress the disadvantaged and disproportionately Black populations that remain in neighborhoods. Thus, policy development and evaluation should consider not only overall investment into communities but the equitable distribution of investments to benefit all individuals within the community. Unfortunately, this study could not specifically evaluate the residential histories of individual cancer patients and thus we are unable to determine how long individuals have resided in present neighborhood, whether their families had resided in the same neighborhood for decades or generations, or whether they have been displaced within the neighborhood. This is a key area of future work dissecting influence of gentrification on cancer care.

Finally, this work highlights how structural racism may disproportionately impact Black populations, but its effects extend to all residents. Over 60% of all of our study patients reside in historically redlined (or hazardous) neighborhoods. Furthermore, the majority of patients residing in Disadvantage Stable neighborhoods and who had late-stage cancer at diagnosis or failed to receive CDS were White. However, racism of all forms continues to be conceptualized as a zero-sum game for many Americans, thinking that gains or improvement for some necessarily means loses or declines for other.[44] Our findings underscore that understanding the impact of structural racism is not only crucial to ensure racial equity but also to improve the overall quality of cancer care for all patients, regardless of race and ethnicity.[45]

These findings should be considered in the context of limitations. First, we used data from seven cities in one state and results may not be generalizable elsewhere in the country. Prior work using HOLC data suggests that redlining elsewhere in the country is associated with multiple adverse health and healthcare outcomes.[18,19,46,47] There was a considerable gap from timing of HOLC map creations (1930's) to present clinical data (2010–2015). Our analysis could be confounded by interval events or dynamics impacting communities. However, we feel that Neighborhood Trajectory provides a novel method to understand not only historical characteristics, but also changes toward present conditions. Additional analyses using specific policy-oriented dates and data would allow for a focused evaluation of interventions' impact on involved communities. Our analysis did not account for where patients were diagnosed or received cancer care. Access to or utilization of designated cancer centers could have influenced our overall findings and Indianapolis is the only city in this study that is also home to a National Cancer Institute Comprehensive Cancer Center.[48] However, our primary models did control for city of residence and outcomes evaluated in this study were comparable between cities. Regardless, these factors including system-level variation in referral patterns and quality of care could play an important role in mediating measured inequity and warrant ongoing evaluation. Our analysis could only account for where patients lived at diagnosis and how this is associated with stage at diagnosis or receipt of CDS. We could not determine if/when patients may have moved into or out of communities. Future longitudinal and cohort studies may provide critical perspectives of patients remaining in or being displaced from neighborhoods with improving socioeconomic

characteristics. Finally, our analyses did not include all possible covariates that can influence decisions about appropriateness of specific clinical actions, including cancer subtype, extent of local invasion, adequacy of surgery, patient comorbidities and goals of care. Therefore, our use of CDS cannot be considered as synonymous with either most appropriate or quality of care.

In conclusion, these data show a significant association between Neighborhood Trajectory and timely diagnosis but not overall rates of CDS for breast or colorectal cancer. However, residence in Disadvantage Reduced or gentrified neighborhood was significantly associated with decreased receipt of CDS for Black compared to White patients. Our findings reinforce the lasting influence of structural racism not just on minoritized populations, but for all residents of socioeconomically marginalized communities. Furthermore, these inequities in cancer care do not exist in a temporal or spatial vacuum but are driven by ongoing policies and practices that shape the world in which we live. Understanding these historic roots, their influence on present environments and the significance of evolving communities vis-à-vis specific policies will be vital to ensure equitable access to and receipt of timely, potentially life-saving cancer surgery.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments:

We would like to recognize Matthew F. Delmont PhD, MA of Dartmouth College Department of History for his initial contributions to study design and interpretation of results in the appropriate historical context. We would also like to acknowledge the Indiana State Cancer Registry for maintaining and providing clinical data used in this report.

Funding:

Support was provided by the GeoSpatial Resource, a section of the Biostatistical and Bioinformatics Shared Resource at the Dartmouth Cancer Center with NCI Cancer Center Support Grant 5P30CA023108 (HAC). Research reported in this publication was also supported by the National Cancer Institute of the National Institutes of Health under award number K08 CA263546 (APL, JEW). No authors have any conflicts of interest to report.

Data Availability Statement:

The data in this article were provided by the Indiana State Cancer Registry with permission granted after review and under terms of a Data Use Agreement. Per this DUA, clinical registry data will not be shared. Investigators interested in use of the Indiana State Cancer Registry can inquire at: https://www.in.gov/health/cdpc/cancer-registry/cancer-registry-home/. HOLC boundaries are available at Mapping inequality: American Panorama, Digital Scholarship Laboratory, University of Richmond at: https://dsl.richmond.edu/panorama/redlining/. Accessed March 16, 2020. United States census block boundaries are publicly available at the US Census website: https://www.census.gov/geographies/reference-maps/2010/geo/2010-census-block-maps.html. The Area Deprivation Index is available through the Neighborhood Atlas at https://www.neighborhoodatlas.medicine.wisc.edu/

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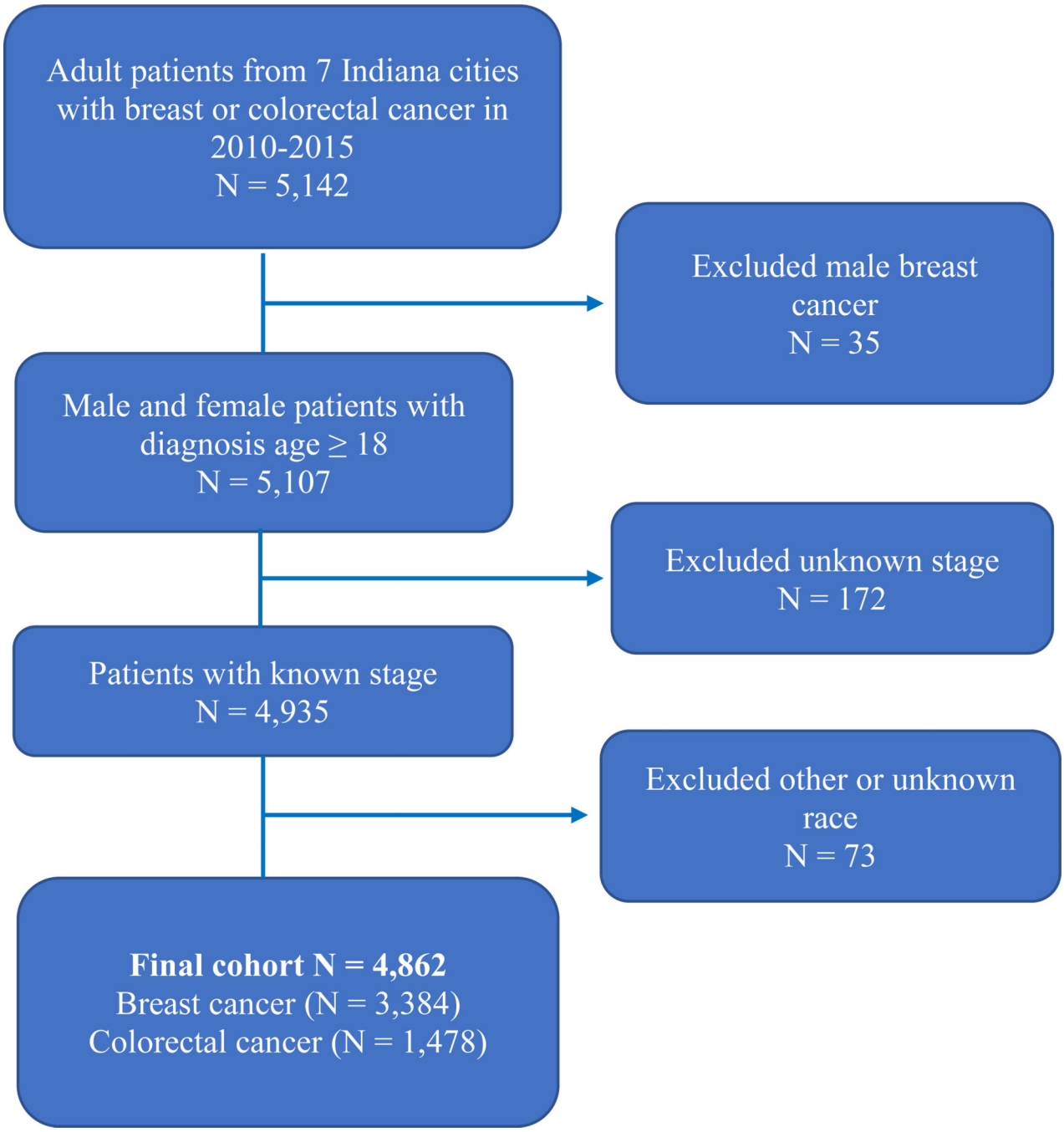

Figure 1.

Cohort derivation among breast and colorectal cancer patients (2010–2015) residing within 7 Indiana cities [α] with assigned block HOLC [β] grade [δ]

[α] The 7 Indiana cities included were: Evansville, Fort Wayne, Indianapolis, Gary, Muncie, South Bend and Terre Haute. [β] HOLC -Home Owners' Loan Corporation. [δ] The block groups received a calculated HOLC score if at least 50% of the block group contained one or more of the 1930's HOLC graded polygons.

Figure 2.
Percentage of study cohort (Indiana cancer patients 2010–2015) by ADI for each HOLC grade

Table 1.

Distribution of patients (N = 4,862) and block group (N = 750) characteristics by Neighborhood Trajectory[α], 2010–2015

	Total (n = 4,862)	Neighborhood Trajectory [α, *] (n = 4,841 ; 746 block groups)			
		Advantage Stable (n = 561; 11.6%)	Disadvantage Reduced (n = 1,054; 21.8%)	Advantage Reduced (n = 299; 6.2%)	Disadvantage Stable (n = 2,927; 60.5%)
Patient characteristics [β]	n (column %) [δ]				
No. of block groups	750 (100.0)	83 (11.1)	112 (15.0)	58 (7.8)	493 (66.1)
Age at diagnosis (continuous, year) [mean (SD)]	63.2 (13.6)	62.4 (13.9)	63.4 (14.0)	62.4 (13.5)	63.3 (13.3)
Age at diagnosis (year)					
18 – 55	1,308 (26.9)	179 (31.9)	273 (25.9)	83 (27.8)	766 (26.2)
55 – 74	2,513 (51.7)	272 (48.5)	538 (51.0)	153 (51.2)	1,537 (52.5)
75+	1,041 (21.4)	110 (19.6)	243 (23.1)	63 (21.1)	624 (21.3)
Sex					
Male	734 (15.1)	199 (23.7)	137 (13.0)	45 (15.1)	477 (16.3)
Female	4,128 (84.9)	640 (76.3)	917 (87.0)	254 (84.9)	2,450 (83.7)
Race/ethnicity					
Non-Hispanic White	3,015 (62.0)	^ (^)	746 (70.8)	^ (^)	1,610 (55.0)
Non-Hispanic Black	1,684 (34.6)	92 (16.4)	280 (26.6)	101 (33.8)	1,197 (40.9)
Hispanic	163 (3.4)	^ (^)	28 (2.7)	^ (^)	120 (4.1)
City					
Evansville	374 (7.7)	35 (6.2)	21 (2.0)	24 (8.0)	294 (10.0)
Fort Wayne	271 (5.6)	48 (8.6)	^ (^)	^ (^)	179 (6.1)
Indianapolis	2,591 (53.3)	332 (59.2)	843 (80.0)	85 (28.4)	1,312 (44.8)
Gary	934 (19.2)	74 (13.2)	141 (13.4)	81 (27.1)	638 (21.8)
Muncie	65 (1.3)	^ (^)	^ (^)	^ (^)	54 (1.8)
South Bend	434 (8.9)	64 (11.4)	43 (4.1)	41 (13.7)	286 (9.8)
Terre Haute	193 (4.0)	^ (^)	^ (^)	19 (6.4)	164 (5.6)
Cancer Type					
Colorectal	1,478 (30.4)	129 (23.0)	264 (25.0)	100 (33.4)	975 (33.3)
Breast	3,384 (69.6)	432 (77.0)	790 (75.0)	199 (66.6)	1,952 (66.7)
Stage					
Stage 0	725 (14.9)	91 (16.2)	178 (16.9)	40 (13.4)	415 (14.2)
Stage I	1,556 (32.0)	211 (37.6)	377 (35.8)	98 (32.8)	863 (29.5)
Stage II	1,264 (26.0)	146 (26.0)	275 (26.1)	89 (29.8)	747 (25.5)

	Total (n = 4,862)	Neighborhood Trajectory [α, *] (n = 4,841 ; 746 block groups)			
		Advantage Stable (n = 561; 11.6%)	Disadvantage Reduced (n = 1,054; 21.8%)	Advantage Reduced (n = 299; 6.2%)	Disadvantage Stable (n = 2,927; 60.5%)
Stage III	742 (15.3)	61 (10.9)	132 (12.5)	37 (12.4)	511 (17.5)
Stage IV	575 (11.8)	52 (9.3)	92 (8.7)	35 (11.7)	391 (13.4)
Cancer-directed surgery [π]	(n = 4,287)	(n = 509; 11.9%)	(n = 962; 22.4 %)	(n = 264; 6.2%)	(n = 2,536; 59.2%)
No	560 (13.1)	54 (10.6)	140 (14.6)	35 (13.3)	328 (12.9)
Yes	3,727 (86.9)	455 (89.4)	822 (85.4)	229 (86.7)	2,208 (87.1)
HOLC grade					
A - Best	320 (6.6)	285 (50.8)	NA	35 (11.7)	NA
B - Still Desirable	540 (11.1)	276 (49.2)	NA	264 (88.3)	NA
C - Definitely Declining	2,920 (60.1)	NA	975 (92.5)	NA	1,929 (65.9)
D - Hazardous	1,082 (22.3)	NA	79 (7.5)	NA	998 (34.1)
ADI group [*]					
Least Deprived (1, 2, 3)	901 (18.6)	338 (60.2)	563 (53.4)	NA	NA
Less Deprived (4, 5, 6)	714 (14.7)	223 (39.8)	491 (46.6)	NA	NA
More Deprived (7, 8)	1,096 (22.6)	NA	NA	183 (61.2)	913 (31.2)
Most Deprived (9, 10)	2,130 (44.0)	NA	NA	116 (38.8)	2,014 (68.8)

Abbreviation: HOLC - Home Owners' Loan Corporation; ADI - Area Deprivation Index; NA - Not Applicable.

[α] Neighborhood Trajectory definitions:

Advantage Stable = HOLC (Best or Still Desirable) and ADI (Least or Less Deprived);

Disadvantage Reduced = HOLC (Definitely Declining or Hazardous) and ADI (Least or Less Deprived);

Advantage Reduced = HOLC (Best or Still Desirable) and ADI (More or Most Deprived);

Disadvantage Stable = HOLC (Definitely Declining or Hazardous) and ADI (More or Most Deprived).

[*] Missing (N): Area Deprivation Index (21) from 4 block groups.

[β] One way analysis of variance and chi-square test results for differences between patient characteristics and Neighborhood Trajectory (p-value): No. of block groups (<0.0001), Age at diagnosis (0.12), Sex (0.01), Race/ethnicity (<0.0001), Diagnosis year (0.44), City (<0.0001), Cancer Type (<0.0001), Stage (<0.0001), HOLC grade (<0.0001), ADI group (<0.0001).

[δ] n (column %) presented unless otherwise specified.

[^] Statistics not displayed due to fewer than 11 cancer cases in at least one patient characteristic group to preserve confidentiality.

[π] Cancer-directed surgery among non-metastatic patients.

Table 2.

Relative risk for late-stage cancer and receipt of cancer-directed surgery by HOLC grade and Neighborhood Trajectory: overall and by cancer type

	Overall	*Colorectal*	*Breast*
	Relative Risk (95% CI)		
	Late Stage		
HOLC grade [α]			
A - Best	Reference	Reference	Reference
B - Still Desirable	1.24 (0.95 – 1.61)	1.04 (0.75 – 1.44)	1.43 (0.93 – 2.22)
C - Definitely Declining	**1.39 (1.10 – 1.75)**	1.27 (0.96 – 1.69)	1.42 (0.97 – 2.08)
D - Hazardous	**1.63 (1.28 – 2.07)**	**1.37 (1.02 – 1.83)**	**1.90 (1.28 – 2.81)**
Neighborhood Trajectory[α, *, β]			
Advantage Stable	Reference	Reference	Reference
Disadvantage Reduced	1.05 (0.87 – 1.26)	1.24 (0.98 – 1.55)	0.83 (0.61 – 1.14)
Advantage Reduced	1.04 (0.81 – 1.33)	1.04 (0.78 – 1.38)	1.01 (0.64 - 1.55)
Disadvantage Stable	**1.35 (1.14 – 1.59)**	**1.30 (1.05 – 1.59)**	**1.41 (1.09 – 1.83)**
	Cancer-directed Surgery [δ]		
HOLC grade [α]			
A - Best	Reference	Reference	Reference
B - Still Desirable	0.98 (0.94 – 1.04)	0.91 (0.79 – 1.06)	1.00 (0.95 – 1.06)
C - Definitely Declining	0.98 (0.94 – 1.02)	0.94 (0.83 – 1.06)	0.99 (0.95 – 1.03)
D - Hazardous	0.98 (0.93 – 1.02)	0.94 (0.82 – 1.07)	0.98 (0.93 – 1.03)
Neighborhood Trajectory[α, *, β]			
Advantage Stable	Reference	Reference	Reference
Disadvantage Reduced	0.98 (0.94 – 1.02)	1.01 (0.89 – 1.13)	0.96 (0.93 – 1.00)
Advantage Reduced	0.97 (0.91 - 1.02)	1.03 (0.88 – 1.19)	0.95 (0.90 – 1.01)
Disadvantage Stable	0.98 (0.95 – 1.01)	1.01 (0.91 – 1.12)	0.98 (0.95 – 1.01)

Abbreviation: HOLC - Home Owners' Loan Corporation;; 95% CI - 95% Confidence Interval; NA – Not Applicable.

[α] Adjusted for patient characteristics of age at diagnosis, sex, diagnosis year, city and cancer type.

[*] Missing (N): Area Deprivation Index (21).

[β] Neighborhood Trajectory definitions:

Advantage Stable = HOLC (Best or Still Desirable) and ADI (Least or Less Deprived);

Disadvantage Reduced = HOLC (Definitely Declining or Hazardous) and ADI (Least or Less Deprived);

Advantage Reduced = HOLC (Best or Still Desirable) and ADI (More or Most Deprived);

Disadvantage Stable = HOLC (Definitely Declining or Hazardous) and ADI (More or Most Deprived).

δCancer-directed surgery among non-metastatic patients and adjusted for patient characteristics and stage.

Table 3.

Relative risk for late-stage cancer by patients' Neighborhood Trajectory by cancer type and patient race/ethnicity

	Overall	*Colorectal*	*Breast*
	Relative Risk (95% CI)		
Neighborhood Trajectory[α, *, β]	Late Stage		
Non-Hispanic White			
Advantage Stable	Reference	Reference	Reference
Disadvantage Reduced	0.98 (0.79 – 1.21)	1.17 (0.91 – 1.50)	0.74 (0.51 – 1.08)
Advantage Reduced	1.02 (0.76 – 1.39)	0.92 (0.65 – 1.31)	1.12 (0.69 – 1.84)
Disadvantage Stable	**1.26 (1.04 – 1.52)**	1.18 (0.95 – 1.48)	**1.37 (1.01 – 1.84)**
Non-Hispanic Black			
Advantage Stable	Reference	Reference	Reference
Disadvantage Reduced	1.41 (0.87 – 2.30)	1.89 (0.96 – 3.75)	1.13 (0.57 – 2.22)
Advantage Reduced	1.17 (0.68 – 2.02)	1.59 (0.77 – 3.28)	0.85 (0.34 – 2.11)
Disadvantage Stable	**1.64 (1.04 – 2.59)**	**1.94 (1.01 – 3.72)**	1.52 (0.82 – 2.79)

Abbreviation: HOLC - Home Owners' Loan Corporation; 95% CI - 95% Confidence Interval; NA – Not Applicable.

[α] Adjusted for patient characteristics of age at diagnosis, sex, diagnosis year, city and cancer type.

[*] Missing (N): Area Deprivation Index (21).

[β] Neighborhood Trajectory definitions:

Advantage Stable = HOLC (Best or Still Desirable) and ADI (Least or Less Deprived);

Disadvantage Reduced = HOLC (Definitely Declining or Hazardous) and ADI (Least or Less Deprived);

Advantage Reduced = HOLC (Best or Still Desirable) and ADI (More or Most Deprived);

Disadvantage Stable = HOLC (Definitely Declining or Hazardous) and ADI (More or Most Deprived).

Table 4.

Racial/ethnic inequity in risk of late-stage cancer and cancer-directed surgery, overall and by Neighborhood Trajectory

		Neighborhood Trajectory [a]			
Race/ethnicity	***Overall***	***Advantage Stable***	***Disadvantage Reduced***	***Advantage Reduced***	***Disadvantage Stable***
	Late Stage [β, *]				
Non-Hispanic White	Reference	Reference	Reference	Reference	Reference
Non-Hispanic Black	1.09 (0.99 – 1.20)	0.79 (0.48 – 1.30)	1.17 (0.92 – 1.48)	1.13 (0.71 – 1.81)	1.10 (0.98 – 1.23)
	Cancer-directed Surgery [*, δ]				
Non-Hispanic White	Reference	Reference	Reference	Reference	Reference
Non-Hispanic Black	0.98 (0.95 – 1.01)	0.94 (0.85 – 1.04)	**0.92 (0.86 – 0.99)**	0.95 (0.84 – 1.08)	1.01 (0.97 – 1.04)

Abbreviation: 95% CI - 95% Confidence Interval; NA – Not Applicable.

[a] Neighborhood Trajectory definitions:

Advantage Stable = HOLC (Best or Still Desirable) and ADI (Least or Less Deprived);

Disadvantage Reduced = HOLC (Definitely Declining or Hazardous) and ADI (Least or Less Deprived);

Advantage Reduced = HOLC (Best or Still Desirable) and ADI (More or Most Deprived);

Disadvantage Stable = HOLC (Definitely Declining or Hazardous) and ADI (More or Most Deprived).

[β] Adjusted for patient characteristics of age at diagnosis, sex, diagnosis year, city and cancer type.

[*] Missing (N): Area Deprivation Index (21).

[δ] Cancer-directed surgery among non-metastatic patients and adjusted for patient characteristics and stage.