Housing Discrimination, Residential Racial Segregation, and Colorectal Cancer Survival in Southeastern Wisconsin

Yuhong Zhou¹, Amin Bemanian¹, Kirsten M. M. Beyer¹

Division of Epidemiology, Institute for Health and Society, Medical College of Wisconsin, Milwaukee, WI

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Corresponding Author
Yuhong Zhou, Institute for Health and Society, Medical College of Wisconsin, 8701 Watertown Plank Road, P.O. Box 26509, Milwaukee, WI 53226-0509, USA.
Phone: 414-955-4302; Fax: 414-955-0176; E-mail: yuzhou@mcw.edu

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No potential conflicts of interest were disclosed.
Abstract

**Background:** Residential racial segregation is still neglected in contemporary examinations of racial health disparities, including studies of cancer. Even fewer studies examine the processes by which segregation occurs, such as through housing discrimination. This study aims to examine relationships among housing discrimination, segregation, and colorectal cancer survival in southeastern Wisconsin.

**Methods:** Cancer incidence data were obtained from the Wisconsin Cancer Reporting System for two southeastern Wisconsin metropolitan areas. Two indices of mortgage discrimination were derived from Home Mortgage Disclosure Act data, and a measure of segregation (the location quotient) was calculated from US census data; all predictors were specified at the Zip Code Tabulation Area (ZCTA) level. Cox proportional hazards regression was used to examine associations between mortgage discrimination, segregation and colorectal cancer survival in southeastern Wisconsin.

**Results:** For all-cause mortality, racial bias in mortgage lending was significantly associated with a greater hazard rate among Blacks (HR=1.37 [1.06, 1.76]) and among Black women (HR=1.53 [1.06, 2.21]), but not Black men in sex-specific models. No associations were identified for redlining or the location quotient. Additional work is needed to determine whether these findings can be replicated in other geographical settings.

**Conclusions:** Our findings indicate that Black women in particular experience poorer colorectal cancer survival in neighborhoods characterized by racial bias in mortgage lending – a measure of institutional racism. These findings are in line with previous study of breast cancer survival.

**Impact:** Housing discrimination and institutional racism may be important targets for policy change to reduce health disparities, including cancer disparities.
Introduction

Colorectal cancer (CRC) is the third leading cause of cancer death in both men and women in the United States (1) and CRC survival disparities, including by race and geography, have been extensively documented (2,3). Despite the continuing decrease in CRC death rates over the past two decades, racial/ethnic minority groups, particularly Blacks/African Americans, continue to have higher death rates compared to whites (1,4,5). The gap in CRC survival rates by race has persisted since the early 1980s (2,3), and may be growing wider (6–8). Studies have shown that diagnosis stage, tumor biology and genetics, comorbidities, lifestyle factors, differences in screening and treatment, and socioeconomic status all can play a role in generating racial disparities in CRC mortality and survival (9–12). However, even after controlling these known contributing factors, the racial survival gap for CRC is not fully eliminated (9).

Researchers are beginning to explore additional factors that may contribute to racial disparities in cancer outcomes, including residential racial segregation (13–15). Research on breast cancer has hypothesized linkages between segregation and survival through health care access, exposure to stressors, and local health behavioral norms, including physical activity, nutrition, tobacco and alcohol use (16,17), and a few studies have indicated that segregation may contribute to racial disparities in cancer mortality, although findings have been mixed (14,17–19). There are far fewer publications investigating the effects of racial residential segregation on CRC outcomes. In a study in the Twin Cities 7-county Metropolitan area, Shen (20) found that facilities that were located closer to minority segregated census tracts had poorer CRC screening performance. In a study exploring the association of segregation with...
disparities in diagnosis stage for breast, colorectal, prostate and lung cancer, Haas et al. (21) found that the Black/White disparity was actually smaller in more segregated areas, after adjusting for individual-level factors and an area-level urban/rural indicator. Given the plausibility of the influence of segregation on CRC survival (13,22), additional work is needed to better understand these relationships.

Although studies of segregation are greatly needed, studying only segregation patterns may not provide sufficient information to inform policy change to improve health and reduce disparities. Segregation measures reveal spatial distributions of population groups by race, but do not directly measure the underlying discriminatory and socioeconomic processes that create the patterns. Processes contributing to segregation patterns involve multiple sectors of society, such as housing, education, and labor (23), and are ultimately the targets for policy changes to reduce residential racial segregation. Recently, several studies have found relationships between mortgage discrimination and health status, including pregnancy health, preterm birth, and most recently, breast cancer survival (24–27), indicating that racial discrimination in housing could be important in explaining racial/ethnic disparities in health outcomes, including cancer. No studies have looked at the relationship between patterns of housing discrimination and CRC survival, and none have concurrently examined housing discrimination and segregation.

The purpose of this study is to examine relationships between housing discrimination segregation, and CRC survival, contributing to a growing body of work examining racism, segregation and cancer outcomes.
Materials and Methods

Study area

The study area includes two metropolitan statistical areas (Milwaukee-Waukesha-West Allis and Racine) in southeastern Wisconsin. As the center of this region, the City of Milwaukee is home to approximately 600,000 residents, of whom non-Hispanic Black and non-Hispanic White populations share similar percentages (39% and 38%). The population within Milwaukee County and the City of Milwaukee experiences lower socioeconomic status (SES) than the state population, including lower incomes, higher poverty, greater unemployment, lower educational attainment, lower home ownership rates and poorer housing stability (28). The long term entrenched poverty and residential racial segregation in Milwaukee, its history of discriminatory housing policies (29), and observed disparities in colorectal cancer incidence and mortality rates (30) make the area an appropriate setting for this study. Figure 1 displays the geographic extent of the study area, as well as patterns of colorectal cancer incidence and mortality in the region, to provide context for the study.

Data and variables

Our analyses are based on three data sources. Cancer incidence data were provided by the Wisconsin Cancer Reporting System (WCRS) for the years 2002-2011 for invasive colorectal cancers for Southeastern Wisconsin. Segregation metrics were calculated from US Census Bureau population and demographic data (31). Indices of mortgage discrimination were derived from Home Mortgage Disclosure Act (HMDA) data (2004-
(2011) available on the Federal Financial Institutions Examination Council (FFIEC) HMDA website. (32)

Reported by hospitals, physicians and clinics directly to DHS, cancer cases include important information about patients' demographics, tumor characteristics and treatment, date and cause of death via linkages to the Wisconsin Vital Records resident death file and National Death Index. The sample used was limited to individuals who are Black or Non-Hispanic White and resided in the study area at diagnosis. Cases missing diagnosis stage information were excluded (< 3%). This study was approved by the Institutional Review Board at the local institution and authorized and approved by the Wisconsin Department of Health Services (DHS) Research Review Board for the release of cancer data for the purpose of cancer prevention and control as defined in Statute 255.04 (3) (c).

The HMDA database was initially created to collect data on mortgage lending practices. It reports relevant information on mortgage applications, such as applicants' demographic and economic characteristics (race/ethnicity, sex, and income), property type, loan purpose, loan amount, and mortgage decision. The census tract containing the residential address of the property for which a mortgage was requested is also included. Data were limited to applications for purchasing an owner-occupied home and without missing information on the primary race/ethnicity, sex and income of the primary applicant, loan amount and whether the loan was denied. Of a total of 396,032 total applications for the purchase of an owner occupied home, approximately 40% of applications were missing data on at least one of these variables; 32% of applications were missing approval/denial status. To mitigate common problems with estimation at
study area boundaries, estimates calculated near the boundaries of the study area also included data from census tracts in counties outside of, but bordering, the study area.

The outcome variable is the survival time post CRC diagnosis, which is calculated as the number of months between initial diagnosis and either date of death or December 31, 2011 (the last day of the study period). Two censoring variables were used based on cause of death information to reflect (1) CRC as the underlying cause of death and (2) all causes of death among men and women diagnosed with CRC. The first variable reflects censoring of individuals who died of causes other than CRC, or were alive on the last day of the study period, while the second variable reflects censoring of only those alive on the last day of the study period.

Primary predictors included two new indices of mortgage discrimination and one segregation metric. Following the work of Beyer et al. (27), we calculated two indices - racial bias in mortgage lending and residential redlining - to measure housing discrimination. Both indices were estimated by integrating logistic regression models with the adaptive spatial filtering (ASF) approach (33,34). To apply ASF, a grid is first laid over the study area, and spatial filters symbolized by circles then are created and centered at each grid point. The idea of ASF is to expand the radius of the filter for each grid point until enough observations from nearby geographic units (census tracts in this case) falling within the filter are obtained to calculate a stable statistic. The statistic is mapped as a continuous surface using Inverse Distance Weighted (IDW) method. The racial bias in mortgage lending index is the statistic estimated for each grid point using the observations within the filter. It is the odds ratio for denial of a mortgage application from a Black primary applicant compared to denial of a White primary applicant, while
controlling for sex, and the ratio of the loan amount to the applicant’s gross annual income. We used a threshold of a minimum of 5 denied Black applicants and 5 denied White applicants to guide the filter size. In contrast, the residential redlining index measures the bias against issuing mortgages in particular neighborhoods. Thus, the redlining index is constructed by estimating the odds of denial of the mortgage application for individuals inside the filter, as compared to individuals outside the filter. The same filter threshold was applied to calculate this index. We derived two variations of the redlining measure - one only adjusting for sex and loan amount to income ratio, and another controlling also the race and ethnicity of the primary applicant. For inclusion in survival models, both indices represented by the interpolated continuous surfaces were summarized (mean pixel value) by ZIP Code Tabulation Area (ZCTA). We also derived binary predictors from them. The binary variable of racial bias index is coded as 1 if the index value is equal to 2 or greater and as 0 otherwise. The cut-off value for coding the binary variable of the redlining index is 1. Although the two redlining measures were both tested, we only reported the results for the one that is race/ethnicity-adjusted, as results were similar.

Segregation was measured at the ZCTA level using the Location Quotient (LQ), a measure of local area segregation(19,35). The equation for calculating LQ is as follows:

\[
LQ_{im} = \frac{x_{im}/X_i}{X_m/X}
\]

where \(LQ_{im}\) is the value for the \(i\)th unit in a region for population group \(m\) (Black in our case); \(x_{im}\) is the number of individuals of the \(m\)th group living in the \(i\)th unit; \(X_i\) is the total number of residents in the \(i\)th unit of the region; \(X_m\) is the total number of individuals
from minority group $m$ in the region; and $X$ is the total number of residents living in the region. The LQ relates the proportion of individuals in a local area of a particular race to the same proportion at the regional level. Conceptually, the LQ represents the relative concentration of a racial group and can explain how the demographic makeup of a single small unit contributes to the overall racial distribution in the metropolitan area(35). The traditional measures of segregation such as dissimilarity and exposure, as outlined by Massey and Denton, quantify how groups are separated within a given area (36). Therefore they are not suitable for measuring the effect of small area’s segregation on a larger region. The unit we employed is ZCTA, to which the CRC cancer cases were geocoded, and the region is confined to the study area. LQ ranges from zero to infinity. An LQ equal to zero indicates that there are no residents of group M in the neighborhood unit, while an LQ less than one indicates that the proportion of group M in the neighborhood is less than the proportion of the same group in the region. Based on the work of Pruitt et al. (19), the LQ was log(x+1) normalized. Calculation of the LQ and mortgage discrimination metrics was completed in R (37) and ArcGIS (38).

Statistical analysis

We used multivariable Cox proportional hazards regression to model survival time for both colorectal-cancer specific mortality and all-cause mortality among Black and Non-Hispanic White individuals diagnosed with incident colorectal cancer in the study area between 2002 and 2011. In addition to the LQ for the Black population and two new indices of mortgage discrimination (each incorporated into the survival model, one at a time), individual characteristics such as age (18-44, 45-54, 55-64, 65-74 and 75+), sex (male and female) and stage at diagnosis (SEER Summary Stage 2000 categories,
local, regional and distant) were included as control variables. Models also control for
two neighborhood-level variables - ZCTA population density and an index of ZCTA
socioeconomic status. The index was estimated using principle components analysis for
selected American Community Survey variables: median household income, percent
unemployed, percent renter households, percent families led by single female, and
percent poverty. For the continuous redlining index and LQ, two different models
with/without adding population density as a covariate were tested, due to a concern
about the moderate correlation between population density and the two primary
predictors. The results for modeling the effects of continuous redlining index
with/without controlling population density are similar in terms of direction, magnitude
and significance, thus we only reported the model results with inclusion of population
density. In total, there are nine models being tested for each outcome variable (six of
which are reported in the results section), examining the LQ and continuous and binary
versions of the racial bias index and two redlining indices. Survival analyses were
implemented in Stata SE/13 (39) and R (37). The proportional hazards assumption was
examined for the models with all the predictors (age, sex, stage at diagnosis, population
density and segregation or mortgage discrimination index), and it was found that the
stage variable often violated the assumption. Thus we applied stratified Cox model to
correct the problem, using the diagnosis stage as a stratification variable. Additionally,
we fitted models with frailty terms for ZCTAs to examine the possibility of spatial
clustering, but no frailty terms were statistically significant. Finally, we fitted additional,
gender-specific models for the Black population to determine whether observed
relationships held for both genders.
Results

Figure 2 displays the spatial distributions of the racial bias index, redlining index while controlling for the race and ethnicity of the primary applicant, and Black LQ.

Table 1 presents descriptive statistics for the population under study. All individuals in the sample are Black/African American or Non-Hispanic White individuals diagnosed with CRC between 2002 and 2011 in the study area. The gender composition is approximately half females and half males. A relatively small proportion of the individuals in the sample were diagnosed with a localized tumor (39.59% among Blacks and 18.79% among Whites). Of those deceased, 265 (38.86%) died from CRC.

Tables 2-4 show the results of Cox proportional hazards models for the racial bias index, redlining, and the location quotient, respectively. For all-cause mortality, the binary racial bias in mortgage lending variable was significantly associated with a greater hazard rate for Blacks (HR=1.37 [1.06, 1.76] in Model 1.2, Table 2), but not for Whites. The racial bias index was not significantly related to CRC specific mortality. The Redlining Index and LQ (Tables 3 and 4) were not significantly associated with all-cause mortality or CRC specific mortality. Of note, although it was not a primary predictor of interest, higher population density was significantly and consistently associated with a higher hazard rate among Whites.

Table 5 shows the results of Cox proportional hazards models for all-cause mortality among Black women diagnosed with CRC. Racial bias in mortgage lending (binary) was associated with poorer CRC survival among Black women, with a hazard ratio comparable to but larger than that observed for the full sample (HR=1.53 [1.06, 2.21] in
Model 4.2, Table 5). Neither the Redlining Index nor the LQ were significantly associated with survival. In male-only models, no measures of segregation or mortgage discrimination were associated with CRC survival.

Discussion

This study contributes new knowledge to a small but growing body of research regarding institutional racism, segregation, and cancer outcomes, helping to shed light on possible directions for policy change and public health intervention. This is the first study to examine linkages between elements of mortgage discrimination and segregation concurrently, in their association with cancer survival, and the first to examine the relationship between mortgage discrimination and colorectal cancer survival. We found that racial bias in mortgage lending (when measured as a binary variable) was related to poorer CRC survival among Blacks, but not among Whites, and that this association was driven by a strong relationship for Black women. Neither redlining nor the LQ exhibited any statistically significant associations, and the only variable of importance for White patients was population density, with higher density associated with a higher hazard rate.

The measures employed in this study are conceptually distinct. While the index of racial bias in mortgage lending indicates the odds of denial of a mortgage application in a particular area by race, the redlining index measures the odds of denial of a mortgage application in a particular neighborhood, regardless of race. The LQ seeks to relate the proportion of a racial group in the local area to the same proportion in the larger region, providing a sense of the relative degree of segregation in a specific local area. In the
study area, the LQ and redlining indices reveal more similar spatial patterns, with higher values in Milwaukee’s predominantly Black central city. In contrast, the racial bias index tends to be higher in areas outside of the central city, where fewer Black residents reside, reinforcing their status as a racial minority.

There are a number of possible explanations for our finding that institutional racism is associated with poorer survival after CRC diagnosis. The long term presence of race-related mortgage discrimination in the Milwaukee area, as a manifestation of institutional racism, could be a persistent source of stress or a barrier to health care access or utilization, thus promoting progression of CRC or hindering recovery and leading to shorter survival of Black CRC patients. The higher likelihood of Black populations being denied to access to financing for housing could indicate possible discrimination in other sectors, reducing access to other resources important to their health and medical needs after diagnosed with CRC. However, it is unclear why this relationship would affect Black women, but not Black men. The small sample size does not appear to have played a role in negative findings for males, as a higher proportion of CRC patients in the database were male. The gender-specific aspects of these relationships require further study.

Interestingly, results did not indicate that individuals living in redlined neighborhoods, or those characterized by high levels of local segregation, experienced poorer CRC specific survival. These findings may seem to run counter to intuition, but do reflect findings from some other studies (14,27). It is possible that Black patients could be exposed to protective factors in predominantly Black central city neighborhoods. In particular, the presence of strong social networks and social support may mitigate the
effects of discrimination or generate protective effects (40). Further, institutional racism in health care access experienced by Black patients living in predominantly White areas may be less of a barrier in areas with higher Black populations, as encounters between Black patients and physicians are likely to be more common. Further study is needed to untangle the practical mechanisms affecting disparate populations.

Our work has several limitations. First, the HMDA data does not include several variables that may affect denial rates, including current employment and credit scores. Second, there are multiple variables for race and ethnicity in the HMDA database and the sensitivity of modeling results to the choice of one variable (race/ethnicity of the primary applicant) versus another (of co-applicant(s)) when deriving indices has not yet been explored. It would be useful to examine the change in patterns of mortgage discrimination when using different definitions of race and ethnicity. Third, the measures of segregation and mortgage discrimination we used only capture the static condition of segregation and mortgage denial patterns during a specific time period, while CRC patients were diagnosed at different times and their exposures to the adverse effects of segregation and discrimination may change with their mobility and life experience. Finally, as measurement is imperfect and not all important factors can be measured with available data, there is of course the possibility that residual or unmeasured confounding could impact effect estimates for the exposures of interest. However, we did control for SES – a major potential source of unmeasured confounding. Further, we did not find evidence of spatial clustering using frailties, providing little evidence of unmeasured spatially-varying confounders.
Despite these limitations, this study presents a novel perspective on the role of housing discrimination and segregation in racial disparities in CRC survival. Future work should examine whether such findings hold for other racial and ethnic groups, and in other geographic settings. In addition, more research is needed to elucidate the pathways by which segregation influences cancer survival disparities and to move these findings toward intervention and population health improvement. Additionally, there are other social/economic processes that contribute to segregation patterns and are worth exploring, such as discrimination in education and labor. Finally, it would be interesting to explore survival between colon and rectum cancer, instead of combining them as colorectal cancer, since their risks for men and women are different (41,42). More translational research on policy development and intervention practices are needed to achieve the ultimate goal of reducing the impact of institutional racism, including mortgage discrimination, on population health.
References


35. Sudano JJ, Perzynski A, Wong DW, Colabianchi N, Litaker D. Neighborhood racial residential segregation and changes in health or death among older adults. Health Place


Table 1. Sample Characteristics

<table>
<thead>
<tr>
<th></th>
<th>White (n=4699)</th>
<th>Black (n = 682)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2465</td>
<td>52.46%</td>
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<tr>
<td>Female</td>
<td>2234</td>
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<td>Age Group</td>
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<td>18-44 years</td>
<td>254</td>
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<td>45-54 years</td>
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<td>55-64 years</td>
<td>865</td>
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<td>65-74 years</td>
<td>1005</td>
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<td>75+ years</td>
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<td>40.69%</td>
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<td>SEER Summary Stage 2000 Categories</td>
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<td>Localized</td>
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<tr>
<td>Regional</td>
<td>1882</td>
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<tr>
<td>Distant</td>
<td>883</td>
<td>18.79%</td>
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<td>Vital Status (as of December 31, 2011)</td>
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<tr>
<td>Alive</td>
<td>2759</td>
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<tr>
<td>Deceased</td>
<td>1940</td>
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<tr>
<td>Cause of Death</td>
<td>(n = 1940)</td>
<td>(n=265)</td>
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<tr>
<td>---------------------</td>
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<tr>
<td>Colorectal Cancer</td>
<td>1159</td>
<td>59.74%</td>
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<tr>
<td>Other Causes</td>
<td>781</td>
<td>40.27%</td>
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Table 2: Cox Proportional Hazards Regression Models Relating **Racial Bias in Mortgage Lending** to All-Cause and Colorectal Cancer Specific Mortality

<table>
<thead>
<tr>
<th>Black patients (n=682)</th>
<th>White patients (n=4699)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1.1</td>
<td>Model 1.2</td>
</tr>
<tr>
<td>HR (95% CI)</td>
<td>HR (95% CI)</td>
</tr>
<tr>
<td>All Cause Survival</td>
<td></td>
</tr>
<tr>
<td>Population Density (100 per sq km)</td>
<td>0.88 [0.64, 1.23]</td>
</tr>
<tr>
<td>Racial Bias Index (continuous)</td>
<td>1.02 [0.92, 1.13]</td>
</tr>
<tr>
<td>Racial Bias Index (Binary; &gt;/=2)</td>
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</tr>
<tr>
<td>Colorectal Cancer Specific Survival</td>
<td></td>
</tr>
<tr>
<td>Population Density (100 per sq km)</td>
<td>0.93 [0.62, 1.39]</td>
</tr>
<tr>
<td>Racial Bias Index (continuous)</td>
<td>1.02 [0.91, 1.14]</td>
</tr>
<tr>
<td>Racial Bias Index (Binary; &gt;/=2)</td>
<td>-- --</td>
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</tbody>
</table>

* * p < 0.05

Table 3: Cox Proportional Hazards Regression Models Relating **Redlining** to All-Cause and Colorectal Cancer Specific Mortality

<table>
<thead>
<tr>
<th>Black patients (n=682)</th>
<th>White patients (n=4699)</th>
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<tbody>
<tr>
<td>Model 2.1</td>
<td>Model 2.2</td>
</tr>
<tr>
<td>HR (95% CI)</td>
<td>HR (95% CI)</td>
</tr>
<tr>
<td>All Cause Survival</td>
<td></td>
</tr>
<tr>
<td>Population Density (100 per sq km)</td>
<td>1.05 [0.73, 1.52]</td>
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<tr>
<td>Redlining Index (continuous)</td>
<td>0.82 [0.66, 1.02]</td>
</tr>
<tr>
<td>Redlining Index (Binary; &gt;/=1)</td>
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<tr>
<td>Colorectal Cancer Specific Survival</td>
<td></td>
</tr>
<tr>
<td>Population Density (100 per sq km)</td>
<td>1.11 [0.71, 1.73]</td>
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### Table 4: Cox Proportional Hazards Regression Models Relating Local Segregation (Black Location Quotient) to All-Cause and Colorectal Cancer Specific Mortality

<table>
<thead>
<tr>
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<th>Black patients (n=682)</th>
<th>White patients (n=4699)</th>
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<tr>
<td></td>
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<tr>
<td>All Cause Survival</td>
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<tr>
<td>Population Density</td>
<td>0.89 [0.64, 1.24]</td>
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<tr>
<td>(100 per sq km)</td>
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<tr>
<td>Black Location Quotient</td>
<td>0.62 [0.29, 1.36]</td>
<td>0.62 [0.29, 1.34]</td>
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<tr>
<td>Colorectal Cancer</td>
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<tr>
<td>Specific Survival</td>
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<tr>
<td>Population Density</td>
<td>1.08 [0.62, 1.40]</td>
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<tr>
<td>(100 per sq km)</td>
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<tr>
<td>Black Location Quotient</td>
<td>0.75 [0.29, 1.98]</td>
<td>0.75 [0.29, 1.97]</td>
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</table>

* p < 0.05

### Table 5. Cox Proportional Hazards Regression Model Predicting All-Cause Mortality among Black Women Diagnosed with Colorectal Cancer (n=356)

<table>
<thead>
<tr>
<th></th>
<th>Model 4.1</th>
<th>Model 4.2</th>
<th>Model 4.1</th>
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<tr>
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<td>HR (95% CI)</td>
<td>HR (95% CI)</td>
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<td>All Cause Survival</td>
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<tr>
<td>Population Density</td>
<td>0.67 [0.40, 1.34]</td>
<td>0.77 [0.45, 1.31]</td>
<td>0.64 [0.37, 1.11]</td>
<td>0.68 [0.41, 1.12]</td>
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<tr>
<td>(100 per sq km)</td>
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</tr>
<tr>
<td>Racial Bias Index</td>
<td>1.12 [0.94, 1.34]</td>
<td>0.77 [0.45, 1.31]</td>
<td>0.64 [0.37, 1.11]</td>
<td>0.68 [0.41, 1.12]</td>
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<tr>
<td>(continuous)</td>
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<tr>
<td>Racial Bias Index</td>
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<tr>
<td>(Binary; &gt;/=2)</td>
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<tr>
<td>Redlining Index</td>
<td>1.53* [1.06, 2.21]</td>
<td>0.89 [0.66, 1.20]</td>
<td>0.65 [0.29, 1.41]</td>
<td>0.96 [0.67, 1.75]</td>
<td>0.31 [0.09, 1.16]</td>
<td>0.38 [0.11, 1.32]</td>
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<td>(continuous)</td>
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<td>Redlining Index</td>
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<tr>
<td>Black Location Quotient</td>
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* p < 0.05
Figure 1. Patterns of Colorectal Cancer Incidence (Panel A) and Mortality (Panel B) in the study area.

The invasive colorectal cancer incidence/mortality rate is indirectly age-sex standardized and smoothed using the adaptive spatial filtering (ASF) approach. A grid of points is used to estimate incidence/mortality rates continuously across the map, based on the 30/20 closest diagnosed/CRC mortality cases. Darker areas indicate higher rates than expected and lighter areas indicate lower rates than expected, given the regional rate. Incidence data is from Wisconsin Cancer Reporting System (WCRS), and mortality data is from the State Vital Records Office.

Figure 2. The Racial Bias in Mortgage Lending Index Maps (panel A and B in the top row), the Race and Ethnicity Adjusted Redlining Index Maps (panel D and E in the bottom row), the Black Location Quotient Map (panel C in the top row).

The graphs (A, B, D, E) for mortgage discrimination measures represent the time period from 2004-2011 and are based on tract level HMDA data. Each of these graphs in a row presents the average pixel value for the index for each ZCTA, and the study area divided into two categories as described for binary indices.
Figure 2

A - Racial Bias Index
B - Racial Bias Index (Binary)
C - Location Quotient
D - Redlining Index
E - Redlining Index (Binary)

Racial Bias Index
- 0.69 - 1.00
- 1.01 - 2.50
- 2.51 - 5.00
- 5.01 - 7.50
- 7.51 - 10.49

Racial Bias Index (Binary)
- <=2
- >2

Location Quotient
- -0.30 to -0.28
- -0.27 to -0.23
- -0.22 to -0.16
- -0.15 to -0.01
- 0.00 to 0.57

Redlining Index
- 0.55 to 1.00
- 1.01 to 1.25
- 1.26 to 1.50
- 1.51 to 2.00
- 2.01 to 2.40

Redlining Index (Binary)
- <=1
- >1

City of Milwaukee
County Boundary

0 3 6 12 18 24 24 Miles
Housing Discrimination, Residential Racial Segregation, and Colorectal Cancer Survival in Southeastern Wisconsin

YUHONG ZHOU, Amin Bemanian and Kirsten M. M. Beyer

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