Research Article

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The Effects of Residential Segregation and Neighborhood Characteristics on Surgery and Survival in Patients with Early-Stage Non–Small Cell Lung Cancer

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Abstract

Background: Although the negative effects of lower socioeconomic status on non–small cell lung cancer (NSCLC) treatment and survival have been widely studied, the impact of residential segregation on prognosis and the receipt of treatment has yet to be determined.

Methods: This is a retrospective, cohort study of NSCLC patients in Georgia (2000–2009; $n = 8{,}322$) using data from the Georgia Comprehensive Cancer Registry. The effects of segregation, economic deprivation, and combined segregation/deprivation on the odds of receiving surgery were examined in separate multilevel models. To determine the association for the exposures of interest on the risk of death for different racial groups, separate multilevel survival models were conducted for black and white patients.

Results: Living in areas with the highest [AOR = 0.35, 95% confidence interval (CI), 0.19–0.64] and second highest (AOR = 0.37, 95% CI, 0.20–0.68) levels of segregation was associated with decreased odds of receipt of surgery. Black patients living in areas with high residential segregation and high economic deprivation were 31% (95% CI, 1.04–1.66) more likely to die, even after surgery was controlled for. For white patients, economic deprivation was associated with decreased odds of surgery but not survival. Segregation had no effect.

Conclusion: Our findings suggest how black and white individuals experience segregation and area-level poverty is likely different leading to differences in adverse health outcomes.

Impact: Identifying neighborhood characteristics impacting health outcomes within different racial groups could help reduce health disparities across racial groups by implementing targeted policies and interventions. *Cancer Epidemiol Biomarkers Prev; 25(5); 750–8. ©2016 AACR.*

Introduction

Lung cancer is the leading cause of cancer-related death in the United States. Approximately 158,000 Americans will die from the disease in 2015, accounting for 27% of all cancer-related deaths (1). Non–small cell lung cancer (NSCLC) is the most common type of lung cancer and accounts for 83% of cases (2). Stage at diagnosis and treatment type are especially important in NSCLC patients given early-stage disease is potentially curable by surgical resection (3). At least half of patients who undergo surgical treatment survive more than 5 years, whereas, without surgery, most will die within a year (3–5). Although surgical resection remains the only reliable treatment for early-stage NSCLC, 29% of patients do not receive surgical treatment (3, 5, 6). Differences in cancer prognosis exist across racial and ethnic groups and are well established (7–9). For lung cancer, these differences are largely due to disparities in the receipt of surgical treatment (3).

Although the Civil Rights Act of 1968 officially made housing discrimination illegal, racial residential segregation remains a persistent problem in the United States (10). Racial and ethnic minorities living in racially segregated neighborhoods are disproportionately affected by a number of health problems including cancer (10–14). Studies have suggested these individuals are diagnosed with more advanced disease for breast and colorectal cancers and are less likely to receive adequate treatment compared with their counterparts living in less segregated areas (15, 16). Another study found that lung cancer mortality was 10% higher in blacks living areas with high segregation, regardless of socioeconomic status (SES; ref. 17). Although the negative effects of lower SES on NSCLC treatment and survival have been widely studied (18–22), the impact of residential segregation on prognosis and the utilization of cancer care have yet to be determined. The only study to date investigating the relationship between segregation and lung cancer found black and Hispanic patients living in highly segregated areas had lower odds of early-stage diagnosis compared with white patients (16).

The purpose of this study was to determine the extent to which residential segregation and other neighborhood characteristics are associated with receipt of surgery and 5-year survival for patients diagnosed with early-stage NSCLC. The outcomes of interest were the odds of receiving surgical treatment and risk of death. The exposures of interest included two census tract-level social and environmental variables: residential segregation and economic

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deprivation, controlling for individual level exposures, and three area-level variables: place of residence (rural, suburban, urban), educational attainment, and elderly concentration. The results of this study are intended to bringing importance to segregation and other characteristics as determinants of lung cancer outcomes. As a result, what is learned from these epidemiologic findings can be applied to interventions and public policies to improve patient outcomes and contribute to the difficult and complex task of reducing racial health disparities.

Materials and Methods

Study design

This is a retrospective cohort study of patients diagnosed with NSCLC in Georgia from January 2000 to December 2009 ($N = 57{,}120$). The termination date for follow-up was January 1, 2012. Data were from the Georgia Comprehensive Cancer Registry (GCCR) which collects data on incident cases of cancer diagnosed in the state. GCCR has 98% case ascertainment (23). The analysis was restricted to patients with early-stage disease ($n = 14{,}484$). Early-stage disease included the presence of tumors categorized as either localized or regional by direct extension only. Patients were sequentially excluded if (i) age at diagnosis was <30 or >85 years ($n = 532$), (ii) they did not identify as black or white race ($n = 90$), (iii) ethnicity was identified as Hispanic ($n = 103$), (iv) they had multiple primary tumors ($n = 4{,}462$), (v) the tumor was diagnosed as small-cell lung cancer ($n = 714$), and (vi) if census tract information was missing ($n = 22$). To remove patients who were not recommended treatment due to poor prognosis because of comorbid disease or advanced lung cancer, patients who died within 2 weeks of diagnosis or who were diagnosed at autopsy were excluded from the study ($n = 239$).

Study variables

The GCCR collects demographic, tumor-related, treatment-related, and follow-up information on all cancer patients diagnosed in the state. GCCR records the census tract (CT) corresponding to the residential address for cancer patients using Geographic Data Technologies (GDT) with 93% of addresses being geocoded to the exact location defined by the 2000 census definitions. Variables of interest included race, sex, age at diagnosis, date of diagnosis, tumor-related information (stage and grade), treatment type, last date of follow-up and vital status at last follow-up. Using the corresponding CT, 2000 U.S. Census data and Rural Urban Commuting Area (RUCA) codes from the U.S. Department of Agriculture were merged with GCCR data (24, 25). RUCA codes were used to classify each patient as urban, suburban, or rural (26–28). Census data was used to obtain measures of CT-level residential segregation and neighborhood characteristics. Because of the highly correlated nature of variables that constitute the multiple dimensions of SES, factor analysis was used to create latent variables (29–31). We used an orthogonal rotation method, Varimax, because it typically results in factors with a small number of medium to large loadings (>0.60) and a larger number of small loadings (<0.40; refs. 30, 32). Using eight variables obtained from census data, the factor analysis resulted in three latent variables: economic deprivation, educational attainment, and elderly concentration (see Table 1 footnotes a list of census variables included for each latent variable). The three latent variables representing social and demographic attributes of census tracts (30, 33) were classified into four categories based on the quartile distribution (34, 35). Residential segregation was measured by isolation index, which captures the probability of living in proximity to individuals from the same racial or ethnic group (16, 36). Isolation index was used, as opposed to dissimilarity index, because it accounts for the relative sizes of groups being compared and is generally considered a better measure for when studying neighborhood characteristics (36–40). To obtain isolation index at the census tract level we used the formula: $I_j = \sum_{i=1}^{n} \left(\frac{x_i}{X}\right)\left(\frac{x_i}{t_i}\right)$ where j is the census tract and i is the block group. X indicates the number of black individuals in the census tract, x_i indicates the number of black individuals in block group i, and t_i is the total population in block group i. The index ranges from zero to one, where a higher score represents a higher level of isolation (16, 41). Because of high correlation between residential segregation and economic deprivation, consistent with Haas and colleagues (16), a third variable was created combining the two (Table 1 footnotes).

Statistical analysis

Categorical data are presented as frequencies and percentages according to race and are compared using the Pearson χ^2 test. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant. Although the primary focus of this study is to examine the odds of surgery and survival for white and black patients separately, we showed white/black disparities in receipt of surgery and survival (unadjusted, adjusted for individual variables, adjusted for individual and area-level variables, and adjusted for interactions).

Because individuals are nested within census tracts and patients within a tract may be more similar than patients residing in other tracts, we conducted multi-level analyses (42) Therefore, census tract random effects were obtained for all fitted models to account for the hierarchical nature of the data. For the outcome receipt of surgery, odds ratios with 95% confidence intervals were obtained through multi-level mixed-effect logistic regression. The effects of segregation, economic deprivation, and combined segregation-deprivation on the odds of receiving surgery were examined in separate models. In all models, adjusted effects were obtained by controlling for the individual-level variables (age, sex, and tumor grade) and area-level variables (place of residence, educational attainment and elderly concentration). In all tables, in addition to the variables of interest, the three control variables at area-level are displayed.

Survival time was calculated from the date of NSCLC diagnosis until the last day of follow-up, the date of death, or the termination of the study. Patients who died after five years were censored at 5-year follow-up. Five-year survival was measured because it is generally used as a benchmark for cancer treatment success (43–45). Survival models measured the effect of economic deprivation, segregation, and combined segregation-deprivation on risk of death in separate models with and without surgery. Adjusted effects were obtained by controlling for the individual-level and area-level variables. To determine the association for the exposures of interest on the risk of death for different racial groups, separate survival models were conducted for black and white patients to capture the effects of these exposures for each group independently. Models were

Table 1. Characteristics of the study population (n = 8,322)

Characteristics	Total, no. (%) or median (95% CI)	White, no. (%) or median (95% CI)	Black, no. (%) or median (95% CI)	*P*
Study population	8,322 (100.0)	6,867 (82.5)	1,455 (17.5)	
Vital status				<0.001
Alive	2,987 (35.9)	2,528 (36.8)	459 (31.5)	
Deceased	5,335 (64.1)	4,339 (63.2)	996 (68.5)	
Median death time (months)	31.3 (29.9–32.4)	32.2 (31.0–34.4)	26.4 (23.9–29.4)	
Gender				0.063
Male	4,610 (55.4)	3,772 (54.9)	838 (57.6)	
Female	3,712 (44.6)	3,095 (45.1)	617 (42.4)	
Age at diagnosis, years				<0.001
30–50	3,157 (37.9)	2,439 (35.5)	718 (49.4)	
51–64	3,090 (37.1)	2,636 (38.4)	454 (31.2)	
65–85	2,075 (24.9)	1,792 (26.1)	283 (19.4)	
Tumor grade				<0.001
Well differentiated	722 (8.7)	613 (8.9)	109 (7.5)	
Moderately differentiated	2,348 (28.2)	1,992 (29.0)	356 (24.5)	
Poorly differentiated	2,411 (29.0)	2,000 (29.1)	411 (28.3)	
Undifferentiated	264 (3.2)	222 (3.2)	42 (2.9)	
Unknown	2,577 (31.0)	2,040 (29.7)	537 (36.9)	
Surgery				<0.001
No	3,619 (43.5)	2,843 (41.4)	776 (53.3)	
Yes	4,703 (56.5)	4,024 (58.6)	679 (46.7)	
Place of residence				<0.001
Urban	4,468 (53.7)	3,503 (51.0)	965 (66.3)	
Suburban	2,492 (29.9)	2,215 (32.3)	277 (19.0)	
Rural	1,362 (16.4)	1,149 (16.7)	213 (14.6)	
Social environment (census tract-level)				
Educational attainment[a]				<0.001
1st quartile (highest)	1,803 (21.7)	1,568 (22.8)	235 (16.2)	
2	2,141 (25.7)	1,749 (25.5)	392 (26.9)	
3	2,355 (28.3)	1,868 (27.2)	487 (33.5)	
4th quartile	2,023 (24.3)	1,682 (24.5)	341 (23.4)	
Elderly concentration[b]				<0.001
1st quartile (lowest)	1,881 (22.6)	1,568 (22.8)	313 (21.5)	
2	2,228 (26.8)	1,917 (28.0)	311 (21.4)	
3	2,213 (26.6)	1,825 (26.6)	388 (26.7)	
4th quartile	2,000 (24.0)	1,557 (22.7)	443 (30.5)	
Economic deprivation[c]				<0.001
1st quartile (lowest)	2,770 (33.3)	2,642 (38.5)	128 (8.8)	
2	2,281 (27.4)	2,074 (30.2)	207 (14.2)	
3	1,887 (22.7)	1,474 (21.5)	413 (28.4)	
4th quartile	1,384 (16.6)	677 (9.9)	707 (48.6)	
Residential segregation[d]				<0.001
1st quartile (lowest)	2558 (30.7)	2490 (36.3)	68 (4.7)	
2	2262 (27.1)	2076 (30.2)	186 (12.8)	
3	2065 (24.8)	1673 (24.4)	392 (26.9)	
4th quartile	1437 (17.3)	628 (9.2)	809 (55.6)	
Combined RS and ED[e]				<0.001
Low RS – Low ED	4159 (50.0)	3973 (57.9)	186 (12.8)	
Low RS – High ED	661 (7.9)	593 (8.6)	68 (4.7)	
High RS – Low ED	892 (10.7)	743 (10.8)	149 (10.2)	
High RS – High ED	2610 (31.4)	1558 (22.7)	1052 (72.3)	

Abbreviations: RS, residential segregation; ED, economic deprivation.

[a]Latent variable includes the following census variables: percent individuals with a high school degree or lower (+), and percent individuals with a college degree or higher (−).

[b]Latent variable includes the following census variables: percent 65 or older (+) and percent female widows (+).

[c]Latent variable includes the following census variables: percent households below the poverty level (+), percent households with a female head of house with children (+), percent households on public assistance (+), and percent married (−).

[d]Census tract–level residential segregation was measured using the Isolation Index.

[e]Combined variable includes residential segregation and economic deprivation latent variables where low = first and second quartiles and high = third and fourth quartiles.

fitted using shared frailty which assumes correlation between patients within the same census tract caused by an unobservable group-level random effect. This effect, known as frailty, if significantly different from zero will result in changes in point estimates and their SEs. The frailty Cox model reduces to the standard Cox model when the random effect is zero (46). Using Stata software package, multi-level Cox proportional hazard was used to obtain hazard ratios with 95% confidence intervals for the relative risk of death. The proportional hazards assumption was evaluated and met for the variables of interest.

Table 2. ORs for receiving surgery and HRs for death among patients with early-stage NSCLC ($n = 8,322$)

Individual-level variable	Receipt of surgery Unadjusted OR (95% CI)	Receipt of surgery AOR[a] (95% CI)	Receipt of surgery AOR[b] (95% CI)	Receipt of surgery AOR[c] (95% CI)
Race				
White	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Black	**0.62 (0.55–0.69)**	**0.57 (0.50–0.66)**	**0.64 (0.55–0.74)**	1.01 (0.71–1.44)
Individual-level variable	**Unadjusted HR (95% CI)**	**Adjusted[a] HR (95% CI)**	**Adjusted[b] HR (95% CI)**	**Adjusted[d] HR (95% CI)**
Race				
White	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Black	**1.18 (1.09–1.27)**	**1.20 (1.12–1.19)**	**1.10 (1.01–1.19)**	1.00 (0.93–1.09)

Abbreviations: OR, unadjusted OR; Ref, referent group; racial groups are non-Hispanic.

[a]Adjusted for age, sex, tumor grade, and random census tract effect.

[b]Adjusted for age, sex, tumor grade, place of residence, educational attainment, elderly concentration, combined segregation-deprivation, and random census tract effect.

[c]Adjusted for age, sex, tumor grade, geographic, educational attainment, elderly concentration, combined segregation-deprivation, the interaction between race and combined segregation-deprivation, and random census tract effect.

[d]Adjusted for age, sex, tumor grade, geographic, educational attainment, elderly concentration, combined segregation-deprivation, surgery, the interaction between surgery and combined segregation-deprivation, and random census tract effect.

Results

Patient characteristics

Our final study population consisted of 8,322 early-stage NSCLC patients, of whom 4,610 (55.4%) were male and 3,712 (44.6%) were female. Table 1 summarizes patient characteristics by race. A larger proportion of black patients (68.5%) than white patients (63.2%) died during the follow-up period. In addition, the median time until death was lower for black patients (26.4 months) than for white patients (32.2 months). Marked differences existed in the receipt of surgical treatment as well (46.7% for black patients vs. 58.6% for white patients). 82.5% of black patients lived in areas with high segregation (levels 3 and 4) compared with 33.6% of white patients.

Surgery

Black patients had 43% lower odds of receiving surgery than white patients when adjusted for patient characteristics [adjusted odds ratio (AOR) = 0.65, 95% confidence interval (CI): 0.56–0.75; Table 2]. This disparity persists after adjusting for area-level variables as seen in Table 2 (AOR = 0.64; 95% CI, 0.55–0.74; Table 2). However, the relationship disappears after further adjustment for the interaction between race and combined segregation-deprivation (Table 2). Results for the relative odds of receiving surgery by race are depicted in Table 3. We will first consider the results for white patients. As shown in Model A, as economic deprivation increased, the odds of receiving surgery decreased (level-2 AOR = 0.85, 95% CI, 0.73–0.98; level-3 AOR = 0.86, 95% CI, 0.73–1.01; level-4 AOR = 0.72, 95% CI, 0.58–0.89), although level-3 was not shown to be significant. For the evaluation of segregation (Model B), only living in areas with medium-low (level-2) black residential segregation was associated with decreased odds of receiving surgery for white patients (AOR = 0.86; 95% CI, 0.74–0.99). No significant associations were observed between living in areas with combined segregation-deprivation and receipt of surgery. BIC comparison suggested Model A (economic deprivation) was the best fit for predicting the odds of receiving surgery among white patients (Table 3). In this model, living in areas with high elderly concentration (levels 3 and 4) and decreasing educational attainment were associated with decreased odds of receiving surgery. Educational attainment demonstrated the largest effect on receiving surgery for white patients. Living in areas with the lowest level of education was associated with 48% decreased odds of receiving surgery (AOR = 0.52; 95% CI, 0.42–0.64) compared with living in areas with the highest educational attainment.

For black participants, higher levels of economic deprivation (Model A) were associated with decreased odds of receiving surgery (level-2 AOR = 0.54, 95% CI, 0.32–0.91; level-3 AOR = 0.47, 95% CI, 0.29–0.75; level-4 AOR = 0.51, 95% CI, 0.32–0.82). As indicated in Model B, living in areas with high levels of segregation was associated with the largest effect on receipt of surgery for black patients. Compared with living in the least segregated areas, living in areas with the highest and second highest levels of segregation were associated with 65% (AOR = 0.35; 95% CI, 0.19–0.64) and 63% (AOR = 0.37, 95% CI, 0.20–0.68) decreased odds of receiving surgery, respectively. In addition, as depicted in Model C, living in segregated areas, regardless of the level of economic deprivation, was associated with decreased odds of receiving surgery for black patients. BIC comparison suggested both Models B and C (residential segregation and the combined variable) were the better fit for predicting the odds of receiving surgery among black patients, compared to Model A (Table 3 footnotes). In Model B, living in suburban areas was associated with decreased odds of receiving surgery compared with residence in urban areas. Educational attainment and elderly concentration were not significantly associated with receipt of surgery for black patients.

Survival

Black patients had 20% increased risk of death compared with white patients when adjusted only for patient characteristics [hazard ratio (HR) = 1.20; 95% CI, 1.12–1.19; Table 2]. This effect reduced after adjusting for area-level variables (HR = 1.10; 95% CI, 1.01–1.19; Table 2). The observed disparity disappeared after adjustment for surgery and its interaction with combined segregation-deprivation.

Black and white patients were examined separately to capture effects for each group independently. We examined the association between the exposures of interest and risk of death both with and without surgery. This allowed us to determine to what extent the increased risk associated with the area-level exposures might be explained by surgery. In Table 4, we report the following for

Table 3. Adjusted ORs for receiving surgery among patients with early-stage NSCLC by race

	Model A: Economic deprivation		Model B: Residential segregation		Model C: Combined RS-ED	
CT-Level variable	White (n = 6,867) AOR[a] (95% CI)	Black (n = 1,455) AOR[a] (95% CI)	White (n = 6,867) AOR[a] (95% CI)	Black (n = 1,455) AOR[a] (95% CI)	White (n = 6,867) AOR[a] (95% CI)	Black (n = 1,455) AOR[a] (95% CI)
Place of residence						
Urban	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Suburban	1.00 (0.85–1.17)	**0.68 (0.48–0.97)**	1.04 (0.88–1.22)	**0.64 (0.45–0.92)**	1.02 (0.87–1.20)	**0.65 (0.46–0.92)**
Rural	1.07 (0.87–1.31)	0.77 (0.51–1.14)	1.08 (0.88–1.32)	0.72 (0.48–1.08)	1.08 (0.88–1.32)	0.76 (0.52–1.12)
Educational attainment						
1st quartile (highest)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
2	**0.66 (0.55–0.79)**	1.13 (0.77–1.66)	**0.68 (0.56–0.81)**	1.39 (0.94–2.07)	**0.67 (0.55–0.80)**	1.36 (0.92–2.02)
3	**0.54 (0.45–0.66)**	0.92 (0.62–1.38)	**0.55 (0.45–0.67)**	1.18 (0.78–1.77)	**0.55 (0.45–0.67)**	1.12 (0.75–1.68)
4th quartile	**0.52 (0.42–0.64)**	0.83 (0.54–1.28)	**0.52 (0.42–0.65)**	1.04 (0.67–1.60)	**0.52 (0.42–0.64)**	1.01 (0.65–1.55)
Elderly concentration						
1st quartile (lowest)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
2	0.97 (0.82–1.16)	0.73 (0.51–1.06)	0.98 (0.82–1.16)	0.74 (0.51–1.07)	0.97 (0.81–1.16)	0.75 (0.52–1.09)
3	**0.74 (0.62–0.89)**	1.03 (0.71–1.49)	**0.72 (0.60–0.87)**	1.06 (0.73–1.54)	**0.72 (0.60–0.87)**	1.06 (0.73–1.55)
4th quartile	**0.78 (0.64–0.94)**	0.92 (0.65–1.31)	**0.75 (0.62–0.91)**	0.95 (0.67–1.35)	**0.76 (0.63–0.92)**	0.94 (0.66–1.35)
Economic deprivation						
1st quartile (lowest)	1.00 (Ref)	1.00 (Ref)	…	…	…	…
2	**0.85 (0.73–0.98)**	**0.54 (0.32–0.91)**	…	…	…	…
3	0.86 (0.73–1.01)	**0.47 (0.29–0.75)**	…	…	…	…
4th quartile	**0.72 (0.58–0.89)**	**0.51 (0.32–0.82)**	…	…	…	…
Racial segregation						
1st quartile (lowest)	…	…	1.00 (Ref)	1.00 (Ref)	…	…
2	…	…	**0.86 (0.74–0.99)**	0.72 (0.37–1.38)	…	…
3	…	…	0.90 (0.76–1.05)	**0.37 (0.20–0.68)**	…	…
4th quartile	…	…	0.83 (0.67–1.03)	**0.35 (0.19–0.64)**	…	…
Combined RS and ED						
Low RS – Low ED	…	…	…	…	1.00 (Ref)	1.00 (Ref)
Low RS – High ED	…	…	…	…	0.90 (0.72–1.12)	0.69 (0.36–1.32)
High RS – Low ED	…	…	…	…	1.05 (0.86–1.28)	**0.34 (0.21–0.58)**
High RS – High ED	…	…	…	…	0.88 (0.76–1.02)	**0.43 (0.29–0.63)**

NOTE: Bayesian Information Criteria (BIC) for white patient models: Model A = 7,631; Model B = 7,637; Model C = 7,638. BIC for black patient models: Model A = 1,758; Model B = 1,738; Model C = 1,737.

Abbreviations: CT, census tract; ED, economic deprivation; Ref, referent group; RS, residential segregation.

[a]Adjusted for the variables listed and age, sex, tumor grade, and random census tract effect.

white patients: Model A – hazard ratios (HR) for economic deprivation with and without surgery; Model B – HR for segregation with and without surgery; and Model C – HR for combined segregation-deprivation with and without surgery. In Table 5 we report similar models for black patients.

Table 4 reports HRs for white patients with early-stage NSCLC. In Models A–C, for the fully adjusted models, there is an increasing risk of death with decreasing educational attainment. Relative to living in areas with the highest educational attainment, white patients living in areas with the lowest educational attainment had 30%–32% increased risk of death. Although accounting for surgery attenuated the effect, declining educational attainment continued to be associated with a statistically significant increasing risk of death in all models for white patients. Across all three models, white patients living in suburbs were 10%–11% less likely to die compared with their urban counterparts. After adjustment for surgery, economic deprivation (Model A), segregation (Model B), and combined segregation-deprivation were not associated with survival.

Table 4 reports HRs for black patients with early-stage NSCLC. Unlike what was observed for white patients, after accounting for surgery, no socioeconomic variables remained significantly associated with survival. However, black patients living in areas with high residential segregation and high economic deprivation (Model C) were 31% more likely to die, even after surgery.

Discussion

Black patients with early-stage NSCLC were less likely to receive surgery than white patients. Black patients also had lower 5-year survival compared with white patients. However, after surgery was accounted for, the survival disparity between black and white patients disappeared suggesting this disparity was explained by differences in receipt of surgery treatment. Living in areas with higher economic deprivation was associated with lower odds of receiving surgery for both black and white patients. However, the impact of other neighborhood characteristics differed by race. For white patients, educational attainment and elderly concentration were associated with reduced odds of surgery; whereas, living in highly segregated areas was associated with lower odds of receiving surgery among black patients. Although, our measure of segregation represents the extent to which black residents are exposed to other black residents, we also examined the effect of living in black segregated neighborhoods for white patients. Previous studies have suggested higher mortality for whites when they lived in black or Hispanic neighborhoods (42, 47). This study, however, found no association between white survival and living in black neighborhoods once surgery is adjusted for.

Two different patterns for survival emerged for white and black patients as well. For white patients, educational attainment and living in suburbs was associated with survival, independent of surgery. However, for black patients, living in highly segregated areas with high levels of poverty was

Table 4. HRs for death among white patients with early-stage NSCLC (n = 6,867)

	Model A: Economic deprivation		Model B: Residential segregation		Model C: Combined RS-ED	
CT-Level variable	**Partially adjusted[a] HR (95% CI)**	**Fully adjusted[b] HR (95% CI)**	**Partially adjusted[a] HR (95% CI)**	**Fully adjusted[b] HR (95% CI)**	**Partially adjusted[a] HR (95% CI)**	**Fully adjusted[b] HR (95% CI)**
Place of residence						
Urban	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Suburban	0.92 (0.84–1.00)	**0.90 (0.82–0.98)**	**0.90 (0.83–0.99)**	**0.89 (0.82–0.97)**	**0.91 (0.83–0.99)**	**0.89 (0.82–0.97)**
Rural	0.90 (0.81–1.01)	0.90 (0.81–1.01)	0.90 (0.80–1.00)	0.90 (0.81–1.00)	0.90 (0.80–1.00)	0.90 (0.81–1.01)
Educational attainment						
1st quartile (highest)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
2	**1.24 (1.12–1.37)**	**1.14 (1.03–1.25)**	**1.21 (1.09–1.34)**	**1.12 (1.01–1.24)**	**1.21 (1.09–1.35)**	**1.12 (1.01–1.24)**
3	**1.30 (1.17–1.45)**	**1.15 (1.03–1.28)**	**1.28 (1.15–1.43)**	**1.14 (1.02–1.27)**	**1.27 (1.14–1.42)**	**1.13 (1.01–1.26)**
4th quartile	**1.49 (1.33–1.68)**	**1.32 (1.18–1.48)**	**1.47 (1.31–1.66)**	**1.30 (1.16–1.46)**	**1.47 (1.31–1.65)**	**1.30 (1.16–1.46)**
Elderly concentration						
1st quartile (lowest)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
2	1.02 (0.92–1.13)	1.02 (0.93–1.13)	1.01 (0.92–1.12)	1.02 (0.92–1.12)	1.02 (0.93–1.13)	1.02 (0.93–1.13)
3	**1.12 (1.01–1.24)**	1.05 (0.95–1.16)	**1.12 (1.01–1.24)**	1.05 (0.95–1.16)	**1.12 (1.01–1.24)**	1.05 (0.95–1.17)
4th quartile	**1.11 (1.01–1.24)**	1.08 (0.97–1.20)	**1.13 (1.01–1.25)**	1.08 (0.97–1.20)	**1.13 (1.01–1.26)**	1.08 (0.97–1.20)
Economic deprivation						
1st quartile (lowest)	1.00 (Ref)	1.00 (Ref)	…	…	…	…
2	1.08 (0.99–1.18)	1.04 (0.96–1.13)	…	…	…	…
3	**1.10 (1.01–1.20)**	1.05 (0.96–1.15)	…	…	…	…
4th quartile	**1.16 (1.03–1.30)**	1.06 (0.94–1.18)	…	…	…	…
Racial segregation						
1st quartile (lowest)	…	…	1.00 (Ref)	1.00 (Ref)	…	…
2	…	…	1.05 (0.96–1.14)	1.03 (0.95–1.12)	…	…
3	…	…	**1.10 (1.01–1.20)**	1.07 (0.98–1.17)	…	…
4th quartile	…	…	1.08 (0.96–1.22)	1.05 (0.93–1.18)	…	…
Combined RS and ED						
Low RS – Low ED	…	…	…	…	1.00 (Ref)	1.00 (Ref)
Low RS – High ED	…	…	…	…	0.98 (0.87–1.11)	0.97 (0.86–1.09)
High RS – Low ED	…	…	…	…	0.99 (0.89–1.11)	1.00 (0.90–1.12)
High RS – High ED	…	…	…	…	**1.11 (1.02–1.21)**	1.06 (0.98–1.15)

Abbreviations: CT, census tract; Ref, referent group; RS, residential segregation; ED, economic deprivation.

[a]Adjusted for the variables listed and age, sex, tumor grade, and random census tract effect.

[b]Adjusted for the variables listed and age, sex, tumor grade, random census tract effect, and surgery.

associated with lower survival. This effect remained statistically significant after adjustment for surgery and other neighborhood characteristics. The fact that neighborhood economic deprivation alone was not significant for black patients but became significant in combination with residential segregation suggests black patients are impacted by the combined negative effects of segregation and poverty. This might be due the fact that census tract measures for SES are calculated on the basis of the total population of the area and the gradient could be stronger for whites (and not blacks or other minority populations) when the majority population is white. Therefore, it is important to tease out the measure of poverty from poverty concentrated in racially/ethnically segregated neighborhood. The latter have been shaped by mechanisms such as the legacy of institutionalized discriminatory housing policy (48) and likely have different social and health effects than poverty that exist outside the context of segregation. Racially segregated areas do not merely reflect the cohabitation of one racial group, rather they are spatial manifestation of discrimination and contribute to economically impoverished conditions by spatially constraining access to education, employment opportunities, and the quality and utilization of medical services (39, 49, 50). Successfully addressing neighborhood economic deprivation generally involves a combination of urban planning and public policy to encourage a shift to more mixed-income neighborhoods (51). Augmenting such measures with interventions and policies that focus on community organizations and political empowerment may be beneficial for reducing heath disparities in racially segregated black communities (52). Communities with economic and political resources are better equipped to influence zoning regulations, ensure employment and educational opportunities, and make successful attempts to avoid noxious facilities (14, 53)

Few studies have examined the association of area-level characteristics with the receipt of treatment or survival for NSCLC patients in the United States. In an earlier study (22) of all NSCLC patients (all stages) we found educational attainment and economic deprivation were associated with receipt of surgery and survival outcomes. Our current study suggests similar associations; although, the characteristics that were meaningful differed for black and white patients. For instance, living in areas with lower educational attainment was associated with lower odds of receiving surgery and high risk of death for white patients, but not for black patients. Erhunmwunsee and colleagues (54) and Shugarman and colleagues (55) both found that living in areas with low SES was associated with poorer survival outcomes for lung cancer patients. We deconstructed SES into three primary components: economic, educational, and demographic. Our findings suggest lower area-level educational attainment, but not economic deprivation, was associated with lower survival for white patients. Thus, education, rather than the economic components of neighborhood SES, is largely responsible for poorer survival outcomes for whites. However, because surgery was found to be a mediator for survival outcomes, for both black and white NSCLC

Table 5. HRs for death among black patients with early-stage NSCLC ($n = 1{,}455$)

	Model A: Economic deprivation		Model B: Residential segregation		Model C: Combined RS-ED	
	Partially adjusted[a]	Fully adjusted[b]	Partially adjusted[a]	Fully adjusted[b]	Partially adjusted[a]	Fully adjusted[b]
CT-Level variable	**HR (95% CI)**	**HR (95% CI)**	**HR (95% CI)**	**HR (95% CI)**	**HR (95% CI)**	**HR (95% CI)**
Place of residence						
Urban	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Suburban	1.03 (0.85–1.24)	0.95 (0.79–1.15)	0.98 (0.81–1.19)	0.90 (0.74–1.09)	1.05 (0.87–1.25)	0.95 (0.79–1.14)
Rural	0.90 (0.72–1.12)	0.84 (0.68–1.04)	0.84 (0.67–1.04)	**0.76 (0.61–0.95)**	0.90 (0.72–1.10)	0.82 (0.66–1.01)
Educational attainment						
1st quartile (highest)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
2	0.93 (0.74–1.15)	0.97 (0.78–1.21)	0.89 (0.71–1.11)	0.98 (0.78–1.22)	0.88 (0.70–1.09)	0.96 (0.77–1.19)
3	1.07 (0.85–1.33)	1.02 (0.82–1.28)	1.04 (0.83–1.29)	1.06 (0.85–1.32)	1.01 (0.81–1.25)	1.02 (0.82–1.27)
4th quartile	1.14 (0.90–1.44)	1.13 (0.90–1.44)	1.13 (0.89–1.43)	1.17 (0.92–1.47)	1.09 (0.86–1.37)	1.13 (0.89–1.42)
Elderly concentration						
1st quartile (lowest)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
2	1.22 (0.99–1.50)	1.12 (0.91–1.37)	1.20 (0.98–1.47)	1.12 (0.91–1.37)	1.21 (0.99–1.48)	1.12 (0.92–1.37)
3	1.17 (0.95–1.43)	1.15 (0.94–1.42)	1.12 (0.91–1.38)	1.14 (0.93–1.40)	1.13 (0.92–1.39)	1.14 (0.93–1.41)
4th quartile	1.22 (0.99–1.48)	1.18 (0.97–1.43)	1.20 (0.98–1.46)	1.18 (0.97–1.44)	1.19 (0.98–1.45)	1.17 (0.96–1.43)
Economic deprivation						
1st quartile (lowest)	1.00 (Ref)	1.00 (Ref)	…	…	…	…
2	1.03 (0.76–1.39)	0.87 (0.64–1.17)	…	…	…	…
3	**1.33 (1.01–1.73)**	1.09 (0.84–1.43)	…	…	…	…
4th quartile	1.27 (0.97–1.65)	1.13 (0.86–1.47)	…	…	…	…
Racial segregation						
1st quartile (lowest)	…	…	1.00 (Ref)	1.00 (Ref)	…	…
2	…	…	1.16 (0.78–1.75)	1.03 (0.69–1.54)	…	…
3	…	…	**1.64 (1.12–2.39)**	1.26 (0.86–1.85)	…	…
4th quartile	…	…	**1.46 (1.01–2.11)**	1.16 (0.80–1.69)	…	…
Combined RS and ED						
Low RS – Low ED	…	…	…	…	1.00 (Ref)	1.00 (Ref)
Low RS – High ED	…	…	…	…	**1.46 (1.02–2.11)**	1.35 (0.94–1.95)
High RS – Low ED	…	…	…	…	**1.45 (1.08–1.95)**	1.15 (0.85–1.56)
High RS – High ED	…	…	…	…	**1.53 (1.21–1.93)**	**1.31 (1.04–1.66)**

Abbreviations: CT, census tract; ED, economic deprivation; Ref, referent group; RS, residential segregation.

[a]Adjusted for the variables listed and age, sex, tumor grade, and random census tract effect.

[b]Adjusted for the variables listed and age, sex, tumor grade, random census tract effect, and surgery.

patients survival should be understood in connection with treatment disparities and how neighborhood characteristics determine the utilization of surgery.

This study has several strengths. This is the only study to date that investigated the effect of residential segregation on NSCLC treatment and survival outcomes for white and black patients separately. We also attempted to capture the combined effect of neighborhood deprivation and racial segregation by creating a single variable combining the two. Recognizing the importance of surgery on survival outcomes for early-stage NSCLC patients, we analyzed the effects of neighborhood characteristics for the relative odds or receiving surgery and survival. Studies assessing the impact of racial segregation on health tend to measure segregation at the county level. In an attempt to more discriminately capture the racial homogeneity of smaller areas, segregation was measured at the census tract level. Finally, using factor analysis to establish latent variables allowed us to control for different dimensions of the neighborhood environment. This study had some limitations. Individual-level demographic variables were limited to race, gender, and age. Therefore, we were not able to control for other variables such as individual SES, comorbidity, or insurance status. We also lacked information on the cause of death for those participants who died during the follow-up period.

This study revealed that neighborhood characteristics are an important determinant of lung cancer treatment and outcomes. These characteristics differ for black and white patients. Our findings suggest how black and white individuals experience area-level poverty and segregation is likely different leading to differences in adverse health outcomes. Racial segregation represents a phenomenon that is not exclusively about poverty but indicates a broader and more complex setting in which health disparities exist and persist. Therefore, research pertaining to racial disparities should not only consider SES but include racial segregation as an important contextual exposure. Researchers, policymakers and practitioners alike should consider a more careful examination of health disparities, particularly for blacks, in a landscape shaped by historical, social, and institutional forces. Identifying neighborhood characteristics impacting health outcomes within different racial groups could help reduce health disparities across racial groups by implementing targeted policies and interventions. Eliminating the historical mechanisms that has caused much of the structural inequality seen today is merely a first step. Substantial resource investment, community involvement, and political will are all required to actively desegregating towns and cities while maintaining community identity and sense of place within the most affected areas.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

Disclaimer

Stetson University had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript.

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Acquisition of data (provided animals, acquired and managed patients, provided facilities, etc.): A.M. Johnson, R.B. Hines, R. Bayakly
Analysis and interpretation of data (e.g., statistical analysis, biostatistics, computational analysis): A.M. Johnson, A. Johnson, R.B. Hines, R. Bayakly
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Administrative, technical, or material support (i.e., reporting or organizing data, constructing databases): A.M. Johnson, A. Johnson
Study supervision: A.M. Johnson

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