ORIGINAL ARTICLE

Residential Segregation and Lung Cancer Mortality in the United States

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Objective: To examine the relationship between race and lung cancer mortality and the effect of residential segregation in the United States.

Design: A retrospective, population-based study using data obtained from the 2009 Area Resource File and Surveillance, Epidemiology and End Results program.

Setting: Each county in the United States.

Patients: Black and white populations per US county.

Main Outcome Measures: A generalized linear model with a Poisson distribution and log link was used to examine the association between residential segregation and lung cancer mortality from 2003 to 2007 for black and white populations. Our primary independent variable was the racial index of dissimilarity. The index is a demographic measure that assesses the evenness with which whites and blacks are distributed across census tracts within each county. The score ranges from 0 to 100 in increasing degrees of residential segregation.

Results: The overall lung cancer mortality rate was higher for blacks than whites (58.9% vs 52.4% per 100 000 population). Each additional level of segregation was associated with a 0.5% increase in lung cancer mortality for blacks ($P < .001$) and an associated decrease in mortality for whites ($P = .002$). Adjusted lung cancer mortality rates among blacks were 52.4% and 62.9% per 100 000 population in counties with the least (<40% segregation) and the highest levels of segregation (≥60% segregation), respectively. In contrast, the adjusted lung cancer mortality rates for whites decreased with increasing levels of segregation.

Conclusion: Lung cancer mortality is higher in blacks and highest in blacks living in the most segregated counties, regardless of socioeconomic status.

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LUNG CANCER IS THE LEADING cause of cancer mortality in the United States, killing more people than breast, prostate, colon, and ovarian cancers combined.[1] Blacks are disproportionately affected by lung cancer and bear the highest incidence and mortality rates.[2] Among black males, lung cancer mortality is 85.8% compared with 62.7% for white males (per 100 000 population).[2] The explanation for this disparity remains uncertain, and the influence of social determinants with specific reference to residential segregation has been the topic of recent reports addressing health care disparities in cancer care.[2,3] Blacks have comparatively poorer access to specialty physicians, which exacerbates their race-specific cancer profile and allows the outcomes gap between whites and blacks to continue to widen.[4] In this article, we postulate that the negative effect of residential segregation holds true for lung cancer and that segregation across the United States serves as a negative predictor of lung cancer mortality. We hypothesize, therefore, that the more segregated a county, the worse the outcomes. Previous reports have indeed linked lower socioeconomic status, low income, inferior insurance status, and individual lack of resources with poor health outcomes. Segregation is, however, a unique construct in that it examines the population as a unit and allows an opportunity to proffer options for policy implementation directed at large groups. This is the first study, to our knowledge, to examine the specific effect of residential segregation on lung cancer mortality using data inclusive of the entire US population.

See Invited Critique at end of article

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METHODS

The objective of this study was to identify factors associated with age-adjusted lung cancer mortality rates for whites and blacks for each

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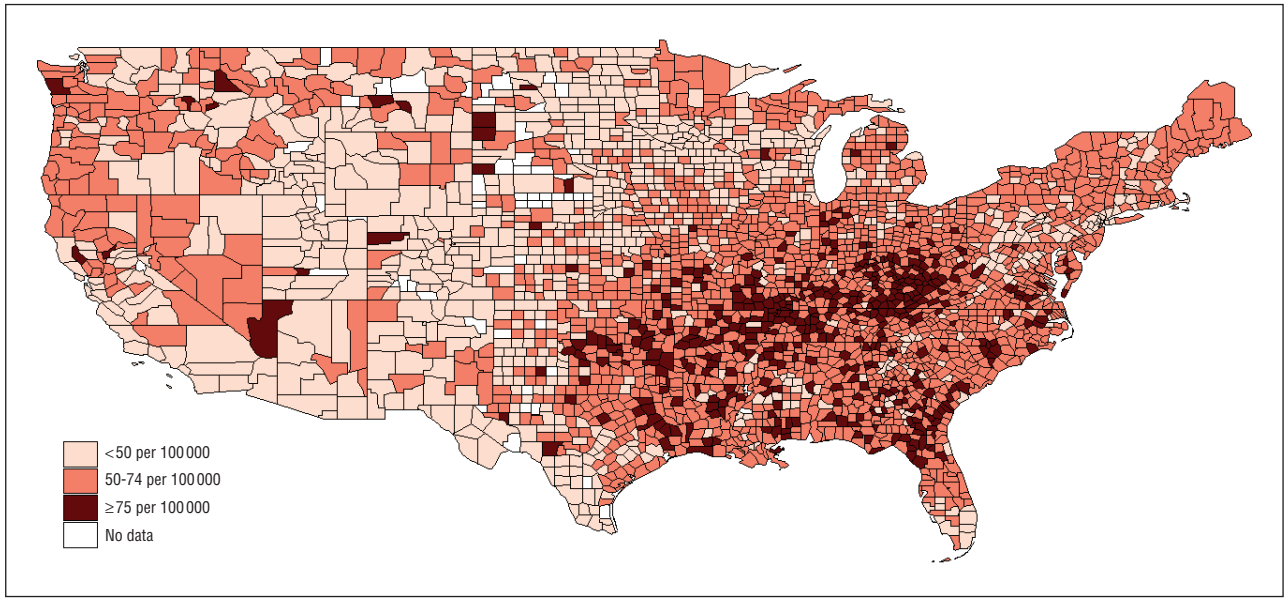

Figure 1. Age-adjusted lung cancer mortality rates for whites.

county in the United States. Race-specific lung cancer mortality rates for each county were calculated using data from the National Center for Health Statistics. Although deaths due to lung cancer were combined for 2003 to 2007 to account for small county size, we were only able to calculate mortality rates for blacks for 1251 of 3701 US counties (33.8%). The mortality rate in each county was age standardized to the US 2000 standard population. County-level mortality rate data were extracted with age standardization.[5,6]

Our primary independent variable was a measure of segregation derived from the Racial Index of Dissimilarity. This index, developed by the Population Studies Center at the University of Michigan, is a demographic measure of segregation that assesses the evenness with which 2 racial groups are distributed across census tracts within each county.[7] For this study, we calculated the dissimilarity of blacks relative to whites. The score ranges from 0 to 100. A score of 0 indicates both groups are proportional across all census tracts in the county, whereas higher scores indicate increasing degrees of residential segregation among census tracts within that county. A score of 60 or higher is considered a very high level of segregation.[8] A score of 90, for example, refers to the percentage of blacks who would have to move to another census tract in a given county to achieve an even distribution of blacks within that county.

The formula for the index of dissimilarity is

$$\tfrac{1}{2}\ \mathrm{SUM}\ (bi/B - wi/W),$$

where bi is the black population of the ith area (eg, county), B is the total black population of the area for which the index of dissimilarity is being calculated, wi is the white population of the ith area, and W is the total white population.[7]

To separate the effect of segregation from other risk factors, we identified a number of other county-level covariates to include from a variety of publicly available data sources. The proportion of adults who are current smokers in each county was identified from the 2007 Behavioral Risk Factor Surveillance System survey.[1] Median per capita income in 2007 in each county was obtained from the Regional Economic Information System from the 2010 Area Resource File. We included population density per square mile and indicators of whether a metropolitan area of more than 1 million residents was located in the county or an adjacent county, as well as an indicator of whether the county included only small towns (<20 000 residents) and was only adjacent to other rural counties. In addition, to account for residual confounding by age, we included as a covariate the proportion of the population who were older than 65 years in 2007, which was obtained from the Area Resource File.

A generalized linear model with a Poisson distribution and log link was used to examine the association of black-white residential segregation and lung cancer mortality.[9] Two separate models were fit: one with lung cancer mortality rates for whites as the primary outcome and another with lung cancer mortality rates for blacks as the primary outcome. The models included smoking rates, county income levels, population density, county proximity to an urban center, and whether the county was considered rural and was adjacent only to other rural counties. Adjusted estimates of the effect of segregation were calculated by fixing all covariates (eg, proportion of adult smokers) to the overall population mean.[10] Survey methods were used to weight each county by its proportion of residents. Maps of US counties were constructed using 2007 county-level boundaries.[11] Counties for Alaska and Hawaii were excluded to simplify figures. All analyses, including construction of maps, were conducted using Stata statistical software, version 11.0 (StataCorp LP).

RESULTS

Of 3701 US counties, 2370 had complete data to calculate lung cancer mortality rates for whites and complete data for all covariates; 1082 counties had complete data for blacks. Most counties where mortality rates for blacks were not calculated or had missing covariate data were sparsely populated, rural counties. After accounting for population weighting, the 2370 counties included in the analysis of lung cancer mortality rates for whites represent 96.7% of the total US population, and the 1082 counties represent 80.0% of the total US population. The overall lung cancer mortality rate between 2003 and 2007 was higher for blacks than for whites (58.9% vs 52.4% per 100 000 population). The distribution of lung cancer mortality rates across the United States is presented in **Figure 1** for whites and in **Figure 2** for blacks.

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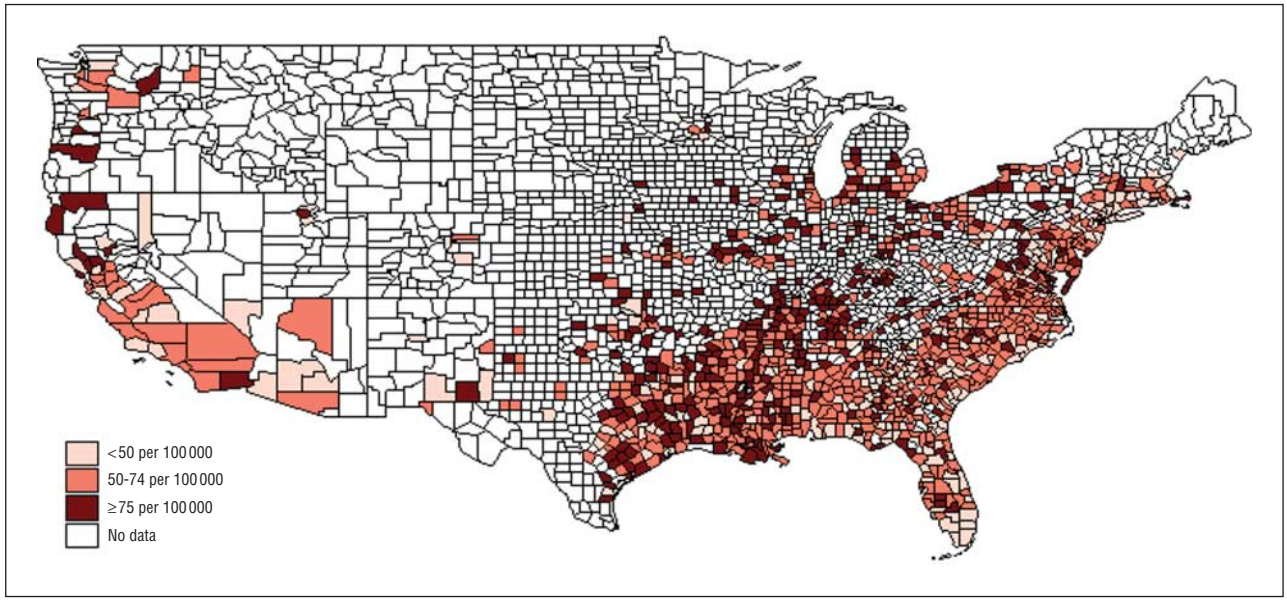

Figure 2. Age-adjusted lung cancer mortality rates for blacks.

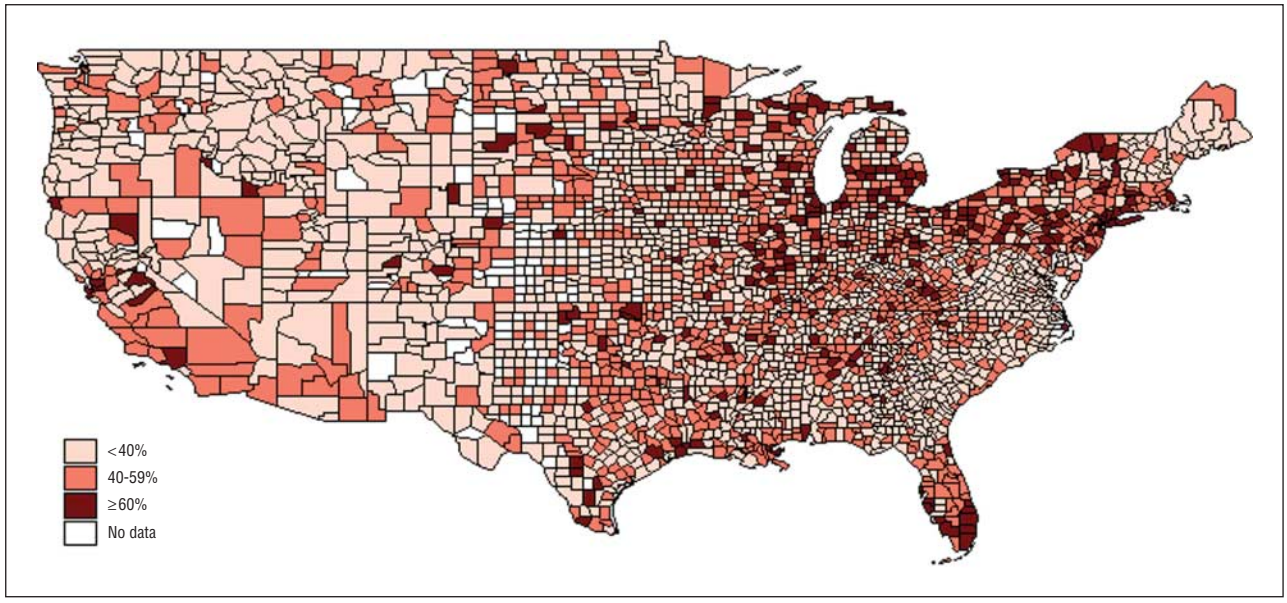

Figure 3. Segregation in the United States by index of dissimilarity scores.

Segregation, as estimated by the index of dissimilarity, ranged widely across the United States, with index of dissimilarity scores from 10 to 100. Overall, the index of dissimilarity score was 51.2% (95% CI, 49.0%-53.4%). We identified that segregation is highest in the Northeast, Midwest, and South and lowest in the Northwest. Counties were stratified into 3 levels of segregation: low segregation, score of less than 40; moderate segregation, score of 40 through 59; and high segregation, score of 60 or higher.[12] Tertiles of the index of dissimilarity were used to facilitate interpretation of the measure. We selected an additional cut point of 40 to divide the remaining counties into groups that represented low and moderate levels of segregation. A total of 28% of the US population lives in counties with low segregation, 40% in counties with moderate segregation, and 32% in counties with high segregation. The distribution of counties in the country with low, moderate, and high levels of segregation is displayed in **Figure 3**.

A model with categorical variables was fit to demonstrate the effect of key covariates on mortality rates (**Table 1**). Counties with moderate levels of racial segregation (index of dissimilarity score, 40%-59%) had lung cancer mortality rates among blacks that were 10% higher than counties with low levels of dissimilarity. Adjusted lung cancer mortality rates among blacks thus ranged from 52.4% (95% CI, 52.1%-52.7%) per 100 000 in counties with lowest segregation levels to 62.9% (95% CI, 62.2%-63.5%) per 100 000 people in counties with high levels of segregation. Adjusted lung cancer mortality rates among whites in counties with low levels of segregation were 53.0% (95% CI, 53.0%-53.1%), decreasing to 50.0% (95%

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Table 1. County-Level Factors Associated With Lung Cancer Mortality Rates for Blacks and Whites in the United States[a]

Factor	Blacks		Whites	
	Relative Risk Ratio	*P* Value	Relative Risk Ratio	*P* Value
Index of dissimilarity score				
Low (<40%)	1.0 [Reference]		1.0 [Reference]	
Moderate (40%-59%)	1.10	.002	1.03	.04
High (≥60%)	1.19	<.001	0.95	.11
Adult smokers in county				
<15%	1.0 [Reference]		1.0 [Reference]	
15%-24%	1.09	.037	1.26	<.001
≥25%	1.23	<.001	1.55	<.001
Median annual household income				
<$25 000	1.0 [Reference]		1.0 [Reference]	
$25 000-$34 999	1.05	.266	0.97	.29
≥$35 000	1.04	.538	0.96	.26
Population size				
County population in (or adjacent to) metro area ≥250 000	0.86	<.001	1.0	.69
County population of 20 000-249 000	1.0 [Reference]		1.0 [Reference]	
County population <20 000	1.10	.05	0.95	.007

[a] Models also adjusted for log population density in county and mean age of county population.

Table 2. Mortality by Level of Segregation

Index of Dissimilarity Score	Adjusted Lung Cancer Mortality per 100 000 Population, % (95% CI)	
	Blacks	Whites
Low (<40%)	52.4 (52.1-52.7)	53.0 (53.0-53.1)
Moderate (40%-59%)	57.0 (56.7-57.3)	51.5 (51.5-51.6)
High (≥60%)	62.9 (62.2-63.5)	50.0 (49.8-50.1)

CI, 49.8%-50.1%) per 100 000 in counties with high levels of segregation (**Table 2**). In adjusted analyses, the lung cancer mortality rate among blacks may thus be associated with increasing levels of segregation after adjusting for covariates. Each percentage increase in the index of dissimilarity was associated with a 0.5% increase in lung cancer mortality among blacks ($P < .001$). In contrast, higher levels of segregation were associated with slightly lower lung cancer mortality rates among whites. Each percentage increase in the index of dissimilarity was associated with a 0.2% decrease in lung cancer mortality rates among whites ($P = .002$). Overall, the spread between lung cancer mortality rates for blacks was large across different levels of segregation, whereas the spread among lung cancer mortality rates for whites was not as strongly influenced by segregation. To demonstrate the effect of segregation, we present the county-level factors associated with lung cancer (Table 1) and the mortality rates for blacks and whites in the United States across the 3 strata of segregation (Table 2).

COMMENT

In this article, we address the effect of residential segregation on lung cancer mortality, examining the possible influence of residential location and neighborhood effects on mortality.[13,14] Blacks living in counties with the highest levels of segregation had a 10% higher mortality rate than those residing in counties with the lowest level of segregation. This increase was not observed among the white population, and, in contradistinction, the mortality rate was 3% lower among whites living in the most segregated counties when compared with those living in the least segregated counties. We thus observed a strong association between residential segregation and higher lung cancer mortality among blacks, whereas segregation was associated with a modest protective effect for whites. These findings persisted even after accounting for smoking prevalence and socioeconomic status, challenging the construct that segregation served as a proxy for socioeconomic status. These findings are consistent with previous reports that have identified that racially segregated environments have higher rates of all-cause mortality, cardiac disease, and infant mortality across all levels of poverty.[14-18] If, however, these results were simply attributed to the availability of resources, then lung cancer mortality would be expected to be similarly increased for both blacks and whites in highly segregated neighborhoods. Clearly, there are other factors as yet undetermined that contribute to this disparity.

This work has a number of limitations. Having performed a cross-sectional analysis, we are unable to make causal inferences at the *individual* level. We are subject to the constraints of having used administrative databases. Whereas it would be an ecologic fallacy to attribute the characteristics of the county to the individual, we also observe that it would be equally fallacious to discount the 10% difference in age- and stage-based lung cancer mortality that might be achieved by changing the residential location of at-risk blacks. Thus, despite the limitations, our study strengths lie in the use of large, national data sets rich in demographic and socioeconomic detail and offering an alternative viewpoint in the approach to disparities. Admittedly, the disparity in lung cancer outcomes is likely the cu-

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mulative effect of various factors, many of which may be difficult to identify, quantify, or mitigate. The physical environment, however, provides a substrate for intervention. By targeting these racially isolated counties, the federal government may be able to improve outcomes at large. Last, our analysis is based on deaths from lung cancer in each county from death certificate records from the National Center for Health Statistics, which do not provide details about the initial diagnosis or treatment patterns. Such data are not available for each county in the United States. Thus, we are unable to examine specific factors, such as stage at diagnosis and intensity of treatment, in the association of segregation with increased mortality among blacks.

Health care disparities, as a whole, have plagued the US health system for the past 3 decades. They have dominated the outcomes research agenda and indeed were the theme of the 97th Annual Clinical Congress of the American College of Surgeons. The higher lung cancer mortality rate that persists among blacks poses a complex problem.[2,7] One possible explanation is that biological mechanisms may contribute to worse outcomes. Pérez-Stable et al[19] reported the presence of higher serum levels of cotinine in blacks compared with whites in response to the same amount of cigarettes smoked. They and others have also found that blacks have 30% higher levels of nicotine despite equivalent cigarette consumption.[18-20] The social environment, occupation, employment, insurance status, and educational level admittedly exert an influence, but by adjusting for socioeconomic status, we attempted to account for these effects.

Residential segregation is a feature of contemporary American society.[21] It has generated a differential in access to employment, housing, and educational opportunities.[18] In 1985, efforts to desegregate public housing were initiated in recognition of its negative social effect.[15] It is conceivable that these ill effects have also contributed to the creation and perpetuation of disparities in health care. Blacks were concentrated in predominantly poor, urban neighborhoods.[15,18] The Federal Housing Administration mortgage insurance program favored one race over another, selectively providing insurance against loss and access to long-term mortgages.[15] Commercial banks, the Veterans Administration, and the federal government "endorsed the use of race restrictive covenants," explicitly refusing to "underwrite loans that would introduce incompatible racial groups into certain residential enclaves" up to as recently as 1950.[15] Blacks are still more likely to be subjected to predatory and discriminatory lending and 30% more likely to receive higher rate subprime loans and to live in census tracts adjacent to industrial waste plants with resultant exposure to increased environmental toxins.[15]

Our data confirm that blacks have been disproportionately affected by segregation and that the greater the segregation, the worse the lung cancer outcomes for this community. The opposing effect on whites was an unexpected finding. This finding could be the result of a number of different reasons, each of which is speculative. The decreased rate may be a positive indication that the ill effects of residential segregation are being mitigated and that these corrective effects are first being witnessed within the majority population living in those counties, making it plausible that the effects will also be felt by the minority population in the near future. On the other hand, this finding may also be an indication that the distribution of resources within counties is still so unevenly balanced within census tracts that blacks are still not able to benefit from them despite living in the same counties. Yet another alternative speculation in the absence of prerequisite insurance data is that whites living in highly segregated counties may be able to travel outside these counties to seek medical care possibly because of more flexible medical insurance coverage or increased receptivity to these individuals in the neighboring areas. Less optimistically still, these findings may merely be the vestiges of lingering discriminatory practices, but each of these may serve as individual hypotheses for further investigation.

Understanding the role, however, played by residential segregation in perpetuating negative outcomes may be invaluable in eliminating disparities altogether. Indeed, this was a federal government goal for 2010 set forth in *Healthy People 2010*.[22] This goal has not been achieved, possibly because of the focus on what the disparities are rather than how they came to exist. The equalization of lung cancer mortality rates between the black and white races might require that counties, or census tracts, of high segregation, with their attendant physical deprivation, social ills, and limited access, receive more attention to address the existing disparities. This equalization may have the theoretical benefit of reducing the mortality rate in blacks, for example, by as much as 10%. Public health initiatives, such as smoking cessation and early cancer screening programs, should be prioritized in these counties. Access to screening and expedient referral to specialist care should be optimized to ensure that the benefits of early cancer screening are realized.[23] In this manner, attempts can be made to address disparities and proffer community-level solutions specifically targeted at ensuring that exposures to environmental hazards are minimized; good air quality is ensured; cancer screening, referral, and treatment occur; and the overall disadvantage of isolation is attenuated. Real estate banking should ensure fair lending and nondiscriminatory practices to allow social mobility and residential freedom. Further progress, therefore, in eliminating disparities may require an evaluation of the role of residential segregation to guide how best to confront the challenges that still remain.

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tical analysis: Zeliadt. *Administrative, technical, and material support:* Zeliadt. *Study supervision:* Hayanga and Backhus.
Conflict of Interest Disclosures: None reported.
Disclaimer: The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the US government.
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INVITED CRITIQUE

Pushing the Envelope of Disparity Research to Find Modifiable Factors

Racial disparity in patient outcomes has been described extensively in the literature. One may wonder, then, what is novel about the study on lung cancer disparity in the United States by Hayanga et al.[1]

Traditionally, clinical research has focused on patient factors, such as age, sex, comorbidities, and cancer staging. The fundamental problem with focusing on patient factors is that they are impossible to change. Herein lies the futility that many feel about disparity research. If poor outcomes are associated with certain ethnoracial groups, what can we do about it? We can't possibly change someone's race!

However, it has become apparent in recent years that higher system-level factors can also affect patient outcomes, such as surgeon experience, hospital volume, and hospital teaching status. These findings suggest that patient outcomes may be more modifiable. For example, if higher-volume surgeons have better outcomes, then we can advocate for the regionalization of those surgical patients.[2]

Hayanga et al[1] push the envelope even further and examine a level of factor above and beyond the surgeons and hospitals. By examining racial dissimilarity[3]—essentially, an objective measure of residential segregation—Hayanga et al find that residential segregation may affect patient outcomes. Their conclusion echoes similar findings in social sciences outside the field of medicine. For example, it has been reported that blacks growing up in racially mixed neighborhoods have higher hourly wages than blacks who grow up in predominantly black neighborhoods.[4]

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