## Original Contribution

# The Role of Poverty Rate and Racial Distribution in the Geographic Clustering of Breast Cancer Survival Among Older Women: A Geographic and Multilevel Analysis

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The authors examined disparities in survival among women aged 66 years or older in association with census-tract-level poverty rate, racial distribution, and individual-level factors, including patient-, treatment-, and tumor-related factors, utilization of medical care, and mammography use. They used linked data from the 1992–1999 Surveillance, Epidemiology, and End Results (SEER) programs, 1991–1999 Medicare claims, and the 1990 US Census. A geographic information system and advanced statistics identified areas of increased or reduced breast cancer survival and possible reasons for geographic variation in survival in 2 of the 5 SEER areas studied. In the Detroit, Michigan, area, one geographic cluster of shorter-than-expected breast cancer survival was identified (hazard ratio (HR) = 1.60). An additional area where survival was longer than expected approached statistical significance (HR = 0.4; *P* = 0.056). In the Atlanta, Georgia, area, one cluster of shorter- (HR = 1.81) and one cluster of longer-than-expected (HR = 0.72) breast cancer survival were identified. Stage at diagnosis and census-tract poverty (and patient's race in Atlanta) explained the geographic variation in breast cancer survival. No geographic clusters were identified in the 3 other SEER programs. Interventions to reduce late-stage breast cancer, focusing on areas of high poverty and targeting African Americans, may reduce disparities in breast cancer survival in the Detroit and Atlanta areas.

breast neoplasms; cluster analysis; geography; population groups; poverty; survival

About 60% of breast cancer deaths occur in women aged 65 years or older (1). Breast cancer screening and more effective therapies have combined to improve breast cancer survival, and an estimated 1 million women aged 65 years or older are currently living with breast cancer (2), a number that is expected to increase over time as the baby boomer generation ages.

It is well established that patient characteristics, tumor-related factors, and type of treatment received affect breast cancer survival (3, 4). In addition to these individual-level factors, there has been increasing interest in the extent to which area-level determinants (e.g., racial distribution, poverty rate) influence breast cancer-related behavior and outcomes, including breast cancer screening, incidence, stage at diagnosis, and mortality (5–9).

The geographic variation in these individual-level and area-level characteristics may contribute to geographic disparities in breast cancer survival that appear to exist in Europe and in the United States (10–16). Identification of reasons for disparities in small-area variation in breast cancer survival will allow for local implementation of evidence-based approaches according to clinical and community guidelines (17, 18) in an effort to reduce such disparities.

The purpose of this study was to examine small-area geographic variation in breast cancer survival among elderly women residing in 5 urban areas in the United States.

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The study of the effect of area-level conditions on breast cancer survival is especially important for older populations, because they may have had longer exposure to adverse neighborhood physical and psychosocial stressors and have a greater need for proximity to health care, food, and other resources and services. Older adults are vulnerable to adverse neighborhood conditions, with negative effects on both biologic and psychologic outcomes (19). In addition, we examined the role that patient factors, type of treatment received, tumor characteristics, utilization of medical care, mammography use, and 2 area-level factors (census-tract percent African American as a measure of racial segregation and census-tract poverty rate as a measure of economic segregation) played in explaining any geographic variation that may exist.

## MATERIALS AND METHODS

### Sample selection

The sample for this study was obtained from a database that links data from the 1992–1999 National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) program with 1991–1999 Medicare claims files from the Centers for Medicare and Medicaid (20), which allowed us to obtain patients' comorbidity data at least 1 year prior to their breast cancer diagnosis. Ninety-four percent of cancer patients reported to SEER aged 65 years or older were successfully matched to the Medicare data (20). We used data from the metropolitan areas of Atlanta, Georgia, Detroit, Michigan, San Francisco-Oakland, California, Seattle-Puget Sound, Washington, and the state of Connecticut. In the data, a first primary in-situ or invasive breast cancer was diagnosed in 37,473 women from 1992 to 1999. We excluded 9,537 women who 1) were enrolled in a health maintenance organization at any point during the 1991–1999 study period, because claims data about key prognostic variables would not be available; 2) were not covered by Medicare Parts A and B between the first primary breast cancer diagnosis and the study end point (date of death or December 31, 1999); 3) were identified by death certificate only because survival time cannot be calculated; 4) had a bilateral mastectomy; and 5) were aged 65 years at diagnosis in order to obtain comorbidity data from Medicare during the year before their breast cancer diagnosis because Medicare data are not available prior to the age of 65 years. Medicare Part A covers inpatient hospitalization, skilled nursing facility care, and hospice care, while Part B covers both inpatient and outpatient medical services, as well as outpatient therapies, limited medical supplies and medical tests, and some durable medical equipment.

This left 27,936 patients available for the remainder of the study. Women who were included in the analysis were statistically more likely to be diagnosed at an earlier stage and to have a lower tumor grade than those excluded. In addition, women who were included were significantly less likely to be of "other" race, to have surgery, and to have radiation therapy. Differences in percentage were generally small between both groups of women but were statistically significant ($P < 0.05$).

### Measurement of breast cancer survival

The SEER registries ascertain annual vital status through a number of approaches, including contact with physicians and patients, review of death certificates and local obituaries, and matching against the National Death Index and Medicare enrollment data. Patients are classified as lost to follow-up after the last date at which vital status was positively established. For this study, the follow-up cutoff date was December 31, 1999. Data from women lost to follow-up who were alive and from those who died from other causes were censored. We used 5-year survival rates to compare the 5 SEER areas, but we used survival as a continuous variable in our analyses to identify potential clusters.

### Area-level variables

Area-level variables consisted of the poverty rate and the racial distribution (percent African American) at the census-tract level. Addresses of residence of all breast cancer patients were address matched by Geographic Data Technology, Inc. (Lebanon, New Hampshire), in order to recover the census tract and both census-tract variables using 1990 US Census data. The poverty rate is a measure that has been consistently associated with various diseases using different spatial scales, has possible implications for policy recommendations, and is comparable over time (21). The racial distribution of each census tract was based on the percent African Americans of all its residents.

### Individual-level variables

The individual-level variables consisted of 4 different groups of factors: patient factors (age, race, marital status, and comorbidity), type of treatment received (type of surgery, radiation therapy, and chemotherapy), tumor characteristics (stage at diagnosis, histology, estrogen receptor status, tumor grade, and metastases), and utilization of medical care (primary care visits, oncologist visits, and ambulatory-care–sensitive hospitalizations (ACSH), which are considered preventable).

From SEER, we obtained data about TNM [Tumor-Node-Metastasis] stage at diagnosis (in situ, I–IV), tumor grade (well, moderately, poorly, or undifferentiated, or unknown), estrogen receptor status (positive, negative, or unknown), histology (ductal, lobular, mixed, or other/inflammatory), first-course type of surgery (none, breast conserving, mastectomy, or unknown), first-course receipt of radiation therapy (yes, no, or unknown), race (white, African American, other, or unknown), age (66–69, 70–74, 75–79, 80–84, ≥85 years), and marital status (married, not married, or unknown).

From Medicare, we obtained information about comorbidity, chemotherapy, primary-care visit, oncologist visit, ACSH, development of metastases, and use of mammography. We used the Deyo adaptation of the Charlson comorbidity index to measure comorbidity (22, 23). We searched all available *International Classification of Diseases*, Ninth Revision, Clinical Modification (ICD-9-CM), codes in the Medicare files (inpatient, outpatient, physician claims) to identify claims of women from 365 days before to 120 days

after their first primary breast cancer diagnosis. Women who had no Medicare claims during this period were categorized as having unknown comorbidity.

Information on chemotherapy was obtained from the Medicare claims data, which are of adequate validity and completeness (24). We used ICD-9-CM procedure, revenue center, and V codes to define chemotherapy (25). Women were considered to have received chemotherapy for breast cancer if there was at least 1 claim present after the date of diagnosis; other women were coded as not having received chemotherapy.

We used Medicare claims data to identify ACSH, as an indicator of adequate, timely, efficient, and high-quality ambulatory care (26, 27). The ICD-9-CM codes reported as a first or primary diagnosis for each hospitalization were used to determine if a hospitalization could be classified as ACSH (26, 28). Women who had 1 or more ACSH at any time following their breast cancer diagnosis were considered to have less adequate, timely, efficient, or high-quality ambulatory care. This group of women was compared with women who did not have any ACSH following their breast cancer diagnosis.

We used the Health Care Financing Administration provider specialty code in the Medicare data to categorize breast cancer survivors' visits to primary care physicians and oncologists following their diagnosis (29). We used Medicare's ICD-9-CM codes to identify metastases of secondary/unspecified malignant neoplasms of lymph nodes, respiratory/digestive systems, or of other unspecified sites (30).

Mammograms were identified from the Medicare data by Current Procedural Terminology (CPT-4) codes 76090, 76091, and 76092 (American Medical Association, Chicago, Illinois) starting at 7 months after diagnosis. Similar to other studies, this study started the surveillance period at 7 months after diagnosis to allow for initiation and/or completion of first-line treatment, because most patients will have completed their definitive surgery and, as appropriate, radiation and chemotherapy, by that time (31). Since the procedure codes distinguish poorly between screening and diagnostic mammograms (32, 33), we counted 2 mammograms within 30 days of each other as 1 screening mammogram. For claims with screening mammography code 76092, there had to be a screening diagnosis code in the physician's claim (i.e., code V10.3, V15.89, V16.3, V72.5, or V76.1) (34, 35). There is high concordance between claims data and medical record data for mammography use among breast cancer survivors (36). We determined whether or not women had received 1 or more mammograms during each 14-month time period starting 7 months after diagnosis. Women who had a mammogram during each of the 14-month time periods were considered to have received annual mammography. These women were contrasted with women who had mammograms during some but not all time periods and with women who did not have any mammograms.

### Statistical analysis

First, we used the log-rank test for testing differences in survival across the 5 SEER programs.

Second, we used an elliptical spatial scan statistic to identify areas with women of shorter-than-expected, longer-than-expected, or outside any shorter- or longer-than-expected survival clusters (i.e., the area of average length of survival) separately within each of the 5 SEER programs (37). The spatial scan statistic uses a window of variable angles and elliptical shapes that moves across the map of each of the 5 SEER areas separately. The radius of the window varies constantly in size from 2% to a maximum size of 50% of the population. The null hypothesis was that mean breast cancer survival was the same in all windows. The process of cluster detection was run through 999 Monte Carlo permutations of the data set. The analyses were purely geographic assuming an exponential probability distribution without any covariate adjustments. Although the survival time may not be exponentially distributed, the permutation procedure is robust with respect to any possible deviations from this distribution (38). Cluster results were mapped in ArcGIS, version 9, software (Environmental Systems Research Institute, Inc., Redlands, California).

Third, we used a multilevel survival model where women were nested within census tracts. The independent variable was trichotomous (cluster of shorter-than-expected survival, longer-than-expected survival, or average survival). Separate survival models were constructed for each SEER program that contained a cluster of shorter- or longer-than-expected survival. The census-tract variables, patient characteristics, type of treatment, tumor factors, utilization of medical care, and mammography variables were sequentially included as groups of mediating variables in the survival models. Multilevel survival models were constructed to evaluate the influence of the mediating variables on risk of breast cancer death. Each of these groups of variables was added separately to the model to examine its effect on the hazard ratio for the women living in a cluster of shorter- or longer-than-expected survival. Changes in these hazard ratios were considered evidence for the mediating effects of these groups of variables (39).

We used restricted iterative generalized least squares (40) and first-order penalized quasi-likelihood estimation (41). The random components were assessed at the individual and census-tract level. Multilevel survival models were fitted by using MLwiN, version 2.0.2, software (42).

## RESULTS

During the study period, 2,817 women died from breast cancer, and 4,236 women died from other causes across the 5 SEER programs. Breast cancer survival varied across the 5 SEER programs ($P < 0.001$). Five-year breast cancer survival rates were similar for women in the San Francisco-Oakland and Seattle areas at 89.5% and 88.1%, respectively, and slightly higher than each of the other 3 areas (Connecticut, 85.3%; Detroit area, 85.8%; Atlanta area, 85.9%). Similar results were obtained across SEER program sites when controlling for stage at diagnosis.

Characteristics of the study participants across the 5 areas are listed in Table 1. Variation across the 5 areas existed with respect to patient characteristics and both

**Table 1.**   Breast Cancer, Patient, and Area-Level Characteristics of the Study Population at 5 SEER Program Sites, 1992–1999

|  | Detroit, Michigan | Atlanta, Georgia | Seattle, Washington | San Francisco, California | Connecticut |
|---|---|---|---|---|---|
| Breast cancer characteristics |  |  |  |  |  |
| Breast cancers, no. | 7,867 | 2,920 | 5,504 | 4,090 | 7,555 |
| Breast cancer deaths, no. (%) | 837 (10.6) | 310 (10.6) | 500 (9.1) | 349 (8.5) | 821 (10.9) |
| 5-year survival rate | 85.8 | 85.9 | 88.1 | 89.5 | 85.3 |
| Patient characteristics |  |  |  |  |  |
| Aged ≥85 years, % | 9.2 | 10.0 | 10.2 | 12.4 | 12.4 |
| African American, % | 16.5 | 19.0 | 1.1 | 7.4 | 3.1 |
| Stage at diagnosis, % |  |  |  |  |  |
| In situ | 14.5 | 12.7 | 11.7 | 13.0 | 12.1 |
| Stage I | 42.0 | 43.1 | 48.6 | 44.3 | 42.5 |
| Stage II | 28.0 | 27.8 | 23.6 | 29.4 | 27.8 |
| Stage III | 5.3 | 5.5 | 7.4 | 4.3 | 4.4 |
| Stage IV | 4.6 | 4.4 | 3.6 | 3.4 | 4.4 |
| Stage unknown | 5.7 | 6.5 | 5.1 | 5.6 | 8.9 |
| Ductal carcinoma, % | 65.7 | 71.6 | 61.7 | 67.4 | 70.5 |
| Two or more comorbid conditions, % | 26.9 | 18.1 | 16.1 | 16.1 | 18.6 |
| Ambulatory-care–sensitive hospitalization, % | 13.6 | 11.9 | 8.9 | 10.0 | 10.5 |
| Area-level characteristics |  |  |  |  |  |
| Census tracts, no. | 1,088 | 368 | 754 | 842 | 838 |
| Census tracts with at least 1 breast cancer patient, no. | 1,031 | 345 | 699 | 744 | 779 |
| Unknown census tract, % | 0.1 | 0.3 | 0.0 | 1.5 | 1.8 |
| Median census-tract poverty rate (minimum–maximum) | 6.9 (0.0–80.2) | 8.2 (0.0–93.9) | 7.7 (0.0–79.4) | 6.1 (0.0–100.0) | 3.8 (0.0–100.0) |
| Median census-tract percent African American (minimum–maximum) | 1.5 (0.0–100.0) | 17.8 (0.0–100.0) | 1.2 (0.0–74.8) | 3.8 (0.0–94.1) | 2.2 (0.0–96.0) |
| Correlation between census-tract poverty rate and percent African American | 0.771* | 0.716* | 0.450* | 0.621* | 0.613* |

Abbreviation: SEER, Surveillance, Epidemiology, and End Results.

* $P < 0.001$.

census-tract-level characteristics (poverty rate and percent African American). The correlation between census-tract poverty rate and percent African American varied across the 5 areas, ranging from a low of 0.450 in Seattle to a high of 0.771 in Detroit.

**Cluster analysis of breast cancer survival**

In the Detroit area, one cluster of increased risk of shorter-than-expected breast cancer survival (hazard ratio (HR) = 1.60; $P = 0.001$) was identified (Web Table 1; Web Figures 1 and 2). (This information is described in a supplementary table and the first 2 of 10 supplementary figures; each is referred to as "Web table" or "Web figure" in the text and is posted on the *Journal*'s website (http://aje.oupjournals.org/).) An additional area where survival was longer than expected approached statistical significance (HR = 0.45; $P = 0.056$). In the Atlanta area, one cluster of shorter- (HR = 1.81) and one cluster of longer-than-expected (HR = 0.72) breast cancer survival were

identified (Web Table 1; Web Figures 3 and 4). For the Seattle-Puget Sound, San Francisco-Oakland, and Connecticut areas, we identified no clusters of shorter- or longer-than-expected breast cancer survival (Web Table 1; Web Figures 5–10). We also ran the spatial scan on a maximum of 10% of the population, which showed very similar results.

For Detroit, the 5-year breast cancer survival rates for women in the shorter-than-expected cluster, area of average survival, and longer-than-expected cluster were 77.6%, 87.1%, and 93.2%, respectively. For Atlanta, the 5-year breast cancer survival rates for women in the shorter-than-expected cluster, area of average survival, and longer-than-expected cluster were 75.4%, 87.0%, and 90.0%, respectively. When women in the clusters of shorter-than-expected survival in the 2 cities were excluded, the 5-year breast cancer survival rates were 87.7% and 88.8% for the Detroit and Atlanta SEER programs, respectively. Breast cancer survival still varied across the 5 SEER programs ($P < 0.001$), although differences were smaller.

**Table 2.** Hazard Ratios and 95% Confidence Intervals Measuring the Likelihood of Breast Cancer Patients Living in the Cluster of Shorter-Than-Expected and Those Living in a Cluster of Longer-Than-Expected Breast Cancer Survival Versus Average Survival on Subsequent Risk of Breast Cancer Death by Controlling for Various Mediating Variables for Women Aged 66 Years or Older, Detroit, Michigan, 1992–1999[a]

| Model | Adjustment Variables | Cluster of Shorter-Than-Expected Survival | | Cluster of Longer-Than-Expected Survival | |
|---|---|---|---|---|---|
| | | Hazard Ratio | 95% Confidence Interval | Hazard Ratio | 95% Confidence Interval |
| 1 | None (univariate) | 1.67 | 1.41, 1.98 | 0.48 | 0.32, 0.70 |
| 2 | Patient characteristics | 1.59 | 1.24, 2.05 | 0.48 | 0.33, 0.71 |
| 3 | Tumor characteristics | 1.20 | 0.99, 1.47 | 0.62 | 0.40, 0.95 |
| 3a | Grade | 1.50 | 1.27, 1.79 | 0.52 | 0.36, 0.75 |
| 3b | Histology | 1.65 | 1.38, 1.97 | 0.48 | 0.33, 0.70 |
| 3c | Estrogen receptor status | 1.58 | 1.33, 1.88 | 0.48 | 0.33, 0.70 |
| 3d | Stage at diagnosis | 1.36 | 1.12, 1.67 | 0.58 | 0.38, 0.88 |
| 3e | Metastasis | 1.61 | 1.35, 1.93 | 0.47 | 0.31, 0.69 |
| 4 | Type of treatment received | 1.53 | 1.26, 1.85 | 0.55 | 0.37, 0.82 |
| 5 | Lack of access to primary care | 1.63 | 1.31, 2.04 | 0.59 | 0.38, 0.91 |
| 6 | Surveillance mammography after diagnosis | 1.62 | 1.37, 1.92 | 0.50 | 0.34, 0.73 |
| 7 | Census-tract poverty rate | 1.37 | 1.05, 1.79 | 0.49 | 0.33, 0.71 |
| 8 | Census-tract percent African American | 1.67 | 1.25, 2.21 | 0.48 | 0.32, 0.70 |
| 9 | Stage at diagnosis, census-tract poverty rate | 1.22 | 0.90, 1.65 | 0.59 | 0.39, 0.91 |

[a] Patient characteristics: age, race, marital status, comorbidity, and year of diagnosis. Treatment: type of surgery, radiation therapy, and chemotherapy. Tumor factors: stage at diagnosis, grade, histology, estrogen receptor status, and presence of metastasis. Utilization of medical care: primary care visit, ambulatory-care–sensitive hospitalization, and oncologist visit. Mammography: mammography use starting 6 months after diagnosis.

**Explaining geographic variation**

For Detroit, the multilevel survival model showed that women who lived in the cluster of shorter-than-expected survival were 1.67 times (95% confidence interval (CI): 1.41, 1.98) more likely to die from breast cancer as women who lived in the area with average survival (Table 2, model 1). Women who lived in the cluster with longer-than-expected survival were 0.48 times (95% CI: 0.32, 0.70) as likely to die from breast cancer as those who lived in the area with average survival (Table 2, model 1). Next, we added each of the groups of mediating variables to model 1. Only tumor characteristics, specifically stage at diagnosis, and census-tract poverty rate reduced the hazard ratio relative to model 1 for women in the cluster of shorter-than-expected survival, thereby suggesting mediation. Stage at diagnosis reduced the hazard ratio for women in the cluster of shorter-than-expected survival from 1.67 (95% CI: 1.41, 1.98) in model 1 to 1.36 (95% CI: 1.12, 1.67) in model 3d. Women in the cluster of shorter-than-expected survival were 1.37 times (95% CI: 1.05, 1.79) more likely to die from breast cancer after adjustment for census-tract poverty rate. When both stage at diagnosis and census-tract poverty rate were included (Table 2, model 9), the confidence intervals for the hazard ratio for the cluster of shorter-than-expected survival included unity, suggesting that both variables combined were able to explain the lower breast cancer survival. None of the other variables was able to explain the cluster of shorter-than-expected survival. Moreover, none of the variables was able to explain the cluster of longer-than-expected survival.

For Atlanta, women who lived in the cluster of shorter-than-expected survival were 1.95 times (95% CI: 1.41, 2.69) more likely to die from breast cancer as women who lived in the area of average survival (Table 3, model 1). Women who lived in the cluster of longer-than-expected survival were 0.73 times (95% CI: 0.53, 0.99) as likely to die from breast cancer as those who lived in the area with average survival (Table 3, model 1). When patient's race was added to model 1, the hazard ratio for women who lived in the cluster of shorter-than-expected survival was reduced to 1.70 (95% CI: 1.19, 2.40) (Table 3, model 2b). The hazard ratio was reduced to 1.48 (95% CI: 1.03, 2.14) for the cluster of shorter-than-expected survival when stage at diagnosis was included (Table 3, model 3d). When the census-tract poverty rate was added to model 1, the hazard ratio for women who lived in the cluster of shorter-than-expected survival was reduced to 1.68 (95% CI: 1.17, 2.40) (Table 3, model 7). When all 3 variables were included, women in all 3 areas were equally likely to die from breast cancer (Table 3, model 9). None of the other variables was able to explain the geographic variation in breast cancer survival.

**DISCUSSION**

Our analyses show that breast cancer survival varied not only across the 5 SEER programs but also within 2 of the 5 SEER programs, namely, in Detroit and Atlanta. In both areas, separate clusters of shorter-than-expected survival and longer-than-expected survival were identified. In each of

**Table 3.**   Hazard Ratios and 95% Confidence Intervals Measuring the Likelihood of Breast Cancer Patients Living in the Cluster of Shorter-Than-Expected and Those Living in a Cluster of Longer-Than-Expected Breast Cancer Survival Versus Average Survival on Subsequent Risk of Breast Cancer Death by Controlling for Various Mediating Variables for Women Aged 66 Years or Older, Atlanta, Georgia, 1992–1999[a]

| Model | Adjustment Variables | Cluster of Shorter-Than-Expected Survival | | Cluster of Longer-Than-Expected Survival | |
|---|---|---|---|---|---|
| | | Hazard Ratio | 95% Confidence Interval | Hazard Ratio | 995% Confidence Interval |
| 1 | None (univariate) | 1.95 | 1.41, 2.69 | 0.73 | 0.53, 0.99 |
| 2 | Patient characteristics | 1.62 | 1.13, 2.33 | 0.80 | 0.60, 1.09 |
| 2a | Age group | 1.96 | 1.42, 2.70 | 0.74 | 0.54, 1.00 |
| 2b | Race | 1.70 | 1.19, 2.40 | 0.78 | 0.59, 1.05 |
| 2c | Marital status | 1.87 | 1.39, 2.51 | 0.75 | 0.58, 0.99 |
| 2d | Comorbidity | 1.97 | 1.46, 2.65 | 0.73 | 0.55, 0.99 |
| 3 | Tumor characteristics | 1.43 | 0.96, 2.11 | 0.75 | 0.52, 1.08 |
| 3a | Grade | 1.87 | 1.34, 2.59 | 0.75 | 0.56, 1.02 |
| 3b | Histology | 1.98 | 1.43, 2.74 | 0.75 | 0.55, 1.01 |
| 3c | Estrogen receptor status | 1.96 | 1.44, 2.65 | 0.74 | 0.55, 0.99 |
| 3d | Stage at diagnosis | 1.48 | 1.03, 2.14 | 0.74 | 0.53, 1.03 |
| 3e | Metastasis | 2.05 | 1.52, 2.78 | 0.78 | 0.59, 1.05 |
| 4 | Type of treatment received | 1.88 | 1.33, 2.65 | 0.71 | 0.51, 0.98 |
| 5 | Lack of access to primary care | 1.79 | 1.29, 2.49 | 0.74 | 0.46, 1.02 |
| 6 | Surveillance mammography after diagnosis | 1.84 | 1.32, 2.58 | 0.75 | 0.56, 1.01 |
| 7 | Census-tract poverty rate | 1.68 | 1.17, 2.40 | 0.75 | 0.56, 1.00 |
| 8 | Census-tract percent African American | 1.80 | 1.22, 2.67 | 0.76 | 0.53, 1.08 |
| 9 | Stage at diagnosis, census-tract poverty rate, race | 1.33 | 0.86, 2.91 | 0.77 | 0.55, 1.09 |

[a] Patient characteristics: age, race, marital status, comorbidity, and year of diagnosis. Treatment: type of surgery, radiation therapy, and chemotherapy. Tumor factors: stage at diagnosis, grade, histology, estrogen receptor status, and presence of metastasis. Utilization of medical care: primary care visit, ambulatory-care–sensitive hospitalization, and oncologist visit. Mammography: mammography use starting 6 months after diagnosis.

these 2 SEER programs, census-tract poverty rate and stage at diagnosis played a major role in explaining the presence of these clusters. Race also played a mediating role in Atlanta. In relation to these factors, other patient characteristics (age, marital status, and comorbidity), treatment factors, other tumor factors (grade, histology, estrogen receptor status, and metastases), utilization of medical care, and mammography use explained very little of the variance in survival.

Because of the importance of stage at diagnosis in explaining the geographic variation in breast cancer survival, increasing screening mammography use and appropriate diagnostic follow-up will likely improve survival in the clusters of shorter-than-expected survival. Identification of areas of shorter-than-expected survival allows for geographically targeted efforts to increase mammography use and to improve delays in diagnostic follow-up.

Much has been written about the racial disparity in breast cancer survival that exists and which has been increasing since the 1980s (43, 44). Although differences in treatment variation have been reported to account for racial disparities (45), treatment variation did not play a role in survival among African-American women who lived in the Atlanta cluster of shorter-than-expected survival. Additionally, insurance status as an explanation for racial disparities (45) is

unlikely to have played a role in our study because all women had Medicare insurance. The literature suggests that racial disparities could be reduced by patient-, provider-, and health system-level interventions (44). Without additional studies, it is unclear which interventions should be implemented among African Americans in the Atlanta cluster of shorter-than-expected survival.

There are several mechanisms by which the poverty rate could explain the geographic variation in breast cancer survival. Improving the type of recommended treatment in areas of higher poverty would not be expected to negate the differences between areas of shorter versus average length of survival. However, our data did not capture the extent of the treatment received. Although the SEER–Medicare data did not contain adjuvant endocrine treatment data, it is unlikely that endocrine treatment would mediate the observed association because other types of treatment were not mediators. Additionally, utilization of medical care or surveillance mammography use after diagnosis in areas of higher poverty would not be expected to negate the differences between areas of shorter versus average length of survival. Neither would patient and tumor characteristics beyond stage at diagnosis account for the differences in length of survival between these areas.

Persons who lived in areas with increased poverty rates may have reduced access to local resources, such as grocery stores selling fresh fruits and vegetables (46), which may lead to increased consumption of dietary fat intake, which, in turn, is associated with reduced survival (47). Residents of these areas also may experience increased psychosocial stress, which is associated with reduced survival (48, 49). Persons who live in high poverty areas also may be more likely to seek treatment for their breast cancer at hospitals with fewer annual numbers of breast cancer surgeries, which lower numbers have been associated with adverse breast cancer outcomes (50). Additional studies are needed to determine why breast cancer survivors living in high-poverty census tracts in the clusters of shorter-than-expected survival have reduced survival.

Our study was limited to women participating in the Medicare program from 5 SEER-program registries. Our findings cannot be generalized to women aged 65 years or younger, who resided elsewhere, who were enrolled in a health maintenance organization, and who had only Medicare Part A coverage. About 14% of subjects participated in a health maintenance organization, which varied geographically (51). Although SEER data are considered to be the "gold standard" of cancer surveillance systems, some variables may have been misclassified. This may have biased the findings toward the null. The SEER–Medicare data did not contain information about the women's socioeconomic status. Income and educational attainment are unlikely to have explained our findings, because the effect of individual-level socioeconomic status on breast cancer survival is mixed and often attenuated after correction for stronger prognosticators, such as type of treatment and other factors included in our models (52). Although some breast cancer survivors may receive services from complementary and alternative providers after breast cancer diagnosis, we did not have any information about these providers and were therefore unable to include them in our analysis. Additionally, in the San Francisco-Oakland and Seattle-Puget Sound SEER areas, there is a slightly higher percentage of Asians than African Americans. However, African Americans are typically more segregated than Asians (53). Finally, because of the use of the marginal probability in the SatScan analysis, the presence of one or more census tracts without any women with breast cancer does not affect the results. In fact, there were several census tracts without any breast cancer patients included in the clusters of shorter- or longer-than-expected breast cancer survival for both Detroit and Atlanta.

In conclusion, interventions to reduce late-stage breast cancer, focusing on areas of high poverty and targeting African Americans, may reduce disparities in subsequent clusters of shorter-than-expected breast cancer survival.

## ACKNOWLEDGMENTS

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