Regional Disparities in the Use and Delivery of Adjuvant Radiation Therapy after Lumpectomy for Breast Cancer in the Medicare Population

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Abstract

Purpose: We examined radiation therapy (RT) use among patients with early-stage breast cancer and analyzed the contribution of patient, cancer, and regional factors to the likelihood of RT receipt across Health Service Areas.

Methods and Materials: We identified 13,176 patients aged 66 to 79 years in the Surveillance, Epidemiology, and End Results (SEER) Program—Medicare database who were diagnosed with lymph node-negative breast cancer in 2007 to 2011 and were treated with breast-conserving surgery. Patients were stratified as being at high risk or low risk for recurrence based on National Comprehensive Cancer Network Guidelines. Receipt of RT was studied with 5 modeling approaches to determine whether RT use and regional variation in its use changed based on the risk level of the cohort. Multivariable mixed-effects logistic regression was performed for each outcome. Choropleth maps were used to describe patterns of RT use.

Results: Among high-risk patients, 70.1% received RT, compared with 72.6% of low-risk patients (P = .002). Among patients receiving RT, 60.9% were classified as high-risk, compared with 63.0% of patients who did not receive RT (P = .002). In multivariable analyses, patients in all rural areas had lower odds of receiving RT compared with the entire cohort (odds ratio [OR], 0.73; P < .001) and had lower odds of being high-risk and receiving RT (OR, 0.69; P < .001). Black patients (OR, 0.73; P = .001) and Asian patients (OR, 0.74; P = .004) had decreased likelihood of receiving RT compared with the entire cohort. The regional interclass correlation coefficient (ICC) for the model predicting receipt of RT among all patients was 0.05 and among low-risk patients was 0.06. The regional ICC dropped to 0.02 for the model predicting being both high-risk and receiving RT among all patients.

Conclusions: We observed regional and racial and ethnic disparities in RT receipt among our cohort. Reassuringly, less regional variability was observed for RT receipt among those at high risk for recurrence. Future work is needed to understand the causes of these regional disparities to better serve patients who may benefit from treatment.

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Introduction

In 2020, the estimated number of new cases of invasive breast cancer in the US and estimated number of deaths were 279,100 and 42,690, respectively. Most breast cancer deaths are owing to recurrence of a previously treated early-stage cancer rather than a late-stage de novo metastatic cancer. Adjuvant radiation therapy (RT) administered after breast-conserving surgery is known to substantially decrease the risk of locoregional recurrence and improve survival rates for patients with invasive breast cancer. However, for areas in which RT treatment is available, it is often delivered in suboptimal ways. For example, considerable disparities in time to starting RT after breast-conserving surgery have been identified in certain regions of the US. Evidence shows that many breast cancer deaths may be attributable to disparities in cancer care rather than a lack of effective therapy, suggesting a need for identifying interventions to promote uniformity in more effective treatment methods. This is supported by an observed wide range of mortality rates among different counties. The fourfold difference in the minimum (11.2 deaths per 100,000 women) and maximum (51.6 deaths per 100,000 women) regional mortality highlights the need for intervention targeting health care delivery factors.

Regional variation can also be attributed to other factors (including but not limited to age, race, ethnicity, social and economic status, rurality, and insurance coverage) that may be associated with breast cancer care and mortality. As a result, regional differences in health care delivery are an important area of investigation for the US Medicare population, and geographic heterogeneity is often regarded as a marker for inefficiency of health care delivery.

To develop interventions to improve the quality of cancer care, we must first understand the extent and sources of these region-based disparities. With the main objective of formulating regional intervention strategies, we sought to understand geographic patterns of radiation treatment delivery to prioritize our effort for strategy execution. The focus of our current study was on examining RT use relative to breast cancer recurrence risk levels across the US among women with early-stage breast cancer treated with breast-conserving surgery. We analyzed the contribution of patient and cancer factors on the likelihood of receiving RT across Health Service Areas (HSAs) and well as the contribution of regional variation. HSAs are defined by the Surveillance, Epidemiology, and End Results (SEER) Program—Medicare database as either a single county or cluster of counties that are self-contained with respect to hospital care. We performed multivariable mixed-effects logistic regression on our data using 5 different approaches to evaluate the value of radiation and analyze whether RT receipt and regional variation in its use changed relative to risk for recurrence and the risk level of the cohort.

Methods

This analysis used data derived from the SEER-Medicare linked database. The population-based SEER database includes demographic and clinical characteristics for cancer cases and accounts for approximately 35% of the US population. The Medicare database includes enrollment information and claims for approximately 97% of the US population aged 65 years or older. These files include information about inpatients, outpatients, durable medical equipment, home health, hospice, and physician services and are used to examine health care patterns over time. Approximately 95% of the patients aged 65 years or older who are included in the SEER database have been linked to Medicare data.

Our analysis focused on patients with lymph node—negative breast cancer who had breast-conserving surgery within 12 months of diagnosis. Our cohort was obtained from the 2018 linkage of the SEER-Medicare data set, which includes Medicare claims data up to December 31, 2016, for cancer cases diagnosed between 1991 and 2015. We included female patients diagnosed at age 66 to 79 years between January 1, 2007, and December 31, 2011, with American Joint Committee on Cancer, 6th edition, lymph node—negative stage I-III breast cancer as their first cancer. Patients with ductal carcinoma in situ or who had metastatic disease were not included in this analysis. Patients who had a second breast cancer within 1 year, who were diagnosed at autopsy or death, or whose diagnosis was not pathologically confirmed were excluded. Patients must have been eligible for Medicare owing to age and had continuous enrollment in Medicare Parts A and B from 12 months before their month of diagnosis (for comorbidity score calculation) and for at least 60 months after diagnosis. Patients enrolled in a Health Maintenance Organization plan during this period were excluded to ensure capture of complete claims for cancer treatment. Patients who had undergone mastectomy or who had not received breast-conserving surgery within 12 months of diagnosis were not included. Radiation therapy receipt was defined as treatment within 18 months of diagnosis.

Patients in our cohort were stratified into high-risk or low-risk categories based on National Comprehensive Cancer Network 5.2021 Guidelines for Invasive Breast Cancer. RT receipt was defined as treatment within 18 months of diagnosis to ensure that patients who required multiple surgeries before RT were included in this analysis. Patients who were considered at low risk for recurrence had an option to omit breast irradiation in their treatment plan. These patients were defined as age 70 years or older, having ER-positive tumors, and having received adjuvant hormone therapy as determined by Medicare claims. These criteria were also chosen to correspond with the entry criteria of the randomized CALGB 9343 trial.
study of radiation omission among women who intended to receive hormone therapy, the results of which were initially published in 2004 in manuscript form. Patients whose cancer fell outside the low-risk criteria were considered high-risk and were recommended to undergo radiation therapy.

Choropleth maps to visually analyze regional radiation use for each of the 5 outcomes were created by dividing the proportion of patients receiving RT into tertiles according to each individual model. For the choropleth map describing rurality, HSAs were classified as either all urban, mostly urban, mostly rural, or all rural, based on where the majority of their patients were classified.

Multivariable mixed-effects logistic regression was performed using 5 approaches to study receipt of RT among different risk cohorts: model 1, likelihood of receiving RT in the entire cohort; model 2, likelihood of receiving RT and being high-risk among the entire cohort; model 3, likelihood of receiving RT and being low-risk among the entire cohort; model 4, likelihood of being high-risk among those patients who received RT; and model 5, likelihood of receiving RT among those patients considered low-risk. Models 1, 2, and 3 contained the entire cohort, whereas model 4 used the subset of patients who had received RT and model 5 contained the subset of patients considered at low risk for recurrence. The same regression was applied to all 5 models, but the patients in each of the cohorts used for modeling differed according to the outcome being measured. More details on the classification of these outcomes are shown in Table 1.

We controlled for covariates by treating them as fixed effects. Variables included in the multivariable regression as fixed effects were age, race and ethnicity (non-Hispanic [NH] White; NH Black; Hispanic; NH Asian; and NH Native American, other, or unknown), rurality (all urban, mostly urban, mostly rural, or all rural), ecological socioeconomic status, education, and comorbidity score (0, 1, or ≥2). To calculate ecological socioeconomic status, quintiles were derived using census tract median household income from US census data provided in the SEER-Medicare database; median income by zip code was used for those patients without census tract information. To calculate the ecological education level, quintiles were derived based on the percentage of households using the census and zip code files. Comorbidity scores were created using the Deyo adaptation of the Charlson Comorbidity Index for the 12-month period before cancer diagnosis. Odds ratios (ORs), 95% confidence intervals (CIs), and P values were calculated for each variable in each of the 5 outcomes. HSAs were added as random intercepts to each of the models. An HSA is defined by the National Center for Health Statistics as a geographic area containing 1 or more counties where most residents in the area obtain hospital care from the same hospitals. An intraclass correlation coefficient (ICC) was calculated by $\frac{\sigma^2}{\sigma^2 + 3.29}$, which is the between-HSA variance on a log-odds scale estimated via the mixed-effect logistic regression model for each of the 5 outcomes. The ICC indicates how much of the total variation in the probability of receiving RT is accounted for by the HSAs on the logistic scale and ranges from 0 to 1. An ICC close to 1 indicates a great level of similarity between values in the same cluster, whereas an ICC close to 0 indicates that values in the same cluster differ and are not similar. In this study, the ICC values were used to compare the amount of regional variability effect on our stratified outcomes. All analyses were performed using R statistics package, version 4.0.1.

### Results

Our final cohort consisted of 13,176 patients diagnosed with lymph node-negative breast cancer who had breast-conserving surgery. The median age at diagnosis was 71 years (range, 66-78 years). Approximately 85.9% of patients were White, 5.1% were Black, 4.3% were Hispanic, and 4.1% were Asian. Approximately 61.7% lived in areas defined as “all urban,” and 7.2% were defined as living in “all rural” areas. A greater proportion of minority patients (79.6% of Black patients, 77.2% of Hispanic patients, and 84.1% of Asian patients) lived in areas defined as “all urban,” compared with the 58.9% of White patients. In addition, a larger proportion of White

### Table 1 Descriptions of the 5 outcome variables

|                | RT received | RT not received |
|----------------|-------------|-----------------|
| High risk      | A           | B               |
| Low risk       | C           | D               |
| 1              | $\frac{A + C}{A + B + C + D}$ | The likelihood of receiving RT in the entire population |
| 2              | $\frac{A}{A + B + C + D}$ | The likelihood of receiving RT and being high risk in the entire population |
| 3              | $\frac{C}{A + B + C + D}$ | The likelihood of receiving RT and being low risk in the entire population |
| 4              | $\frac{A}{A + C + D}$ | The likelihood of being high risk in the subpopulation of patients who have received RT |
| 5              | $\frac{C}{C + D}$ | The likelihood of receiving RT in the subpopulation of patients who are considered low risk |

*Abbreviation: RT = radiation therapy.*
| Table 2  Descriptive statistics for patient and cancer factors* |
|----------------------------------|
| **Patients, No. (%)**            |
| **White (n = 11,322)**          | **Black (n = 672)** | **Hispanic (n = 565)** | **Asian (n = 536)** | **Other (n = 81)** | **Overall (n = 13,176)** |
|----------------------------------|
| **Attained diagnosis age (SEER), y** |
| Mean (SD)                        | 71.6 (3.66)         | 71.6 (3.57)             | 71.6 (3.75)         | 71.5 (3.65)        | 71.6 (3.93)             | 71.6 (3.66)             |
| Median (range)                   | 71.0 (66.0-78.0)    | 72.0 (66.0-78.0)        | 71.0 (66.0-78.0)    | 71.0 (66.0-78.0)   | 71.0 (66.0-78.0)        | 71.0 (66.0-78.0)        |
| **Rurality**                     |
| All rural (%)                   | 894 (7.9)           | 22 (3.3)                | 20 (3.5)            | 6 (1.1)            | 11 (13.6)              | 953 (7.2)              |
| Mostly rural (%)                | 958 (8.5)           | 27 (4.0)                | 22 (3.9)            | 6 (1.1)            | 12 (14.8)              | 1025 (7.8)             |
| Mostly urban (%)                | 2807 (24.8)         | 88 (13.1)               | 87 (15.4)           | 73 (13.6)          | 12 (14.8)              | 3067 (23.3)            |
| All urban (%)                   | 6663 (58.9)         | 535 (79.6)              | 436 (77.2)          | 451 (84.1)         | 46 (56.8)              | 8131 (61.7)            |
| **Comorbidities, No.**          |
| 1 (%)                           | 2444 (21.6)         | 182 (27.1)              | 144 (25.5)          | 157 (29.3)         | 18 (22.2)              | 2945 (22.4)            |
| ≥2 (%)                          | 1174 (10.4)         | 148 (22.0)              | 90 (15.9)           | 67 (12.5)          | 10 (12.3)              | 1489 (11.3)            |
| 0 (%)                           | 7704 (68.0)         | 342 (50.9)              | 331 (58.6)          | 312 (58.2)         | 53 (65.4)              | 8742 (66.3)            |
| **Tumor size, cm**              |
| <2 (%)                          | 9489 (83.8)         | 527 (78.4)              | 457 (80.9)          | 457 (85.3)         | 74 (91.4)              | 11004 (83.5)           |
| 2-5 (%)                         | 1797 (15.9)         | 143 (21.3)              | 107 (18.9)          | 78 (14.6)          | 7 (8.6)                | 2132 (16.2)            |
| >5 (%)                          | 36 (0.3)            | 2 (0.3)                 | 1 (0.2)             | 1 (0.2)            | 0 (0)                  | 40 (0.3)               |
| **Tumor grade**                 |
| Differentiated (%)              | 3691 (32.6)         | 146 (21.7)              | 176 (31.2)          | 167 (31.2)         | 27 (33.3)              | 4207 (31.9)            |
| Moderately (%) differentiated (%) | 5003 (44.2)       | 300 (44.6)              | 247 (43.7)          | 240 (44.8)         | 31 (38.3)              | 5821 (44.2)            |
| Poorly differentiated (%)       | 2093 (18.5)         | 188 (28.0)              | 109 (19.3)          | 107 (20.0)         | 18 (22.2)              | 2515 (19.1)            |
| Undifferentiated (%)            | 39 (0.3)            | 3 (0.4)                 | 4 (0.7)             | 2 (0.4)            | 2 (0.4)                | 50 (0.4)               |
| Unknown (%)                     | 496 (4.4)           | 35 (5.2)                | 29 (5.1)            | 20 (3.7)           | 3 (3.7)                | 583 (4.4)              |
| **Education, quintile**         |
| Q1 (%)                          | 2242 (19.8)         | 125 (18.6)              | 153 (27.1)          | 125 (23.3)         | 19 (23.5)              | 2664 (20.2)            |
| Q2 (%)                          | 2281 (20.1)         | 110 (16.4)              | 112 (19.8)          | 120 (22.4)         | 12 (14.8)              | 2635 (20.0)            |
| Q3 (%)                          | 2235 (19.7)         | 111 (16.5)              | 108 (19.1)          | 106 (19.8)         | 16 (19.8)              | 2576 (19.6)            |
| Q4 (%)                          | 2299 (20.3)         | 134 (19.9)              | 98 (17.3)           | 94 (17.5)          | 15 (18.5)              | 2640 (20.0)            |
| Q5 (%)                          | 2265 (20.0)         | 192 (28.6)              | 94 (16.6)           | 91 (17.0)          | 19 (23.5)              | 2661 (20.2)            |

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patients lived in areas defined as mostly urban, mostly rural, and all rural compared with all other races. Among the groups, Black patients had greater frequency of being diagnosed with larger and poorly differentiated cancers, and 51.0% of Black patients and 36.5% of Hispanic patients were in the lowest quintile of socioeconomic status. Descriptive statistics of our final cohort are further summarized in Table 2.

Table 2 displays recurrence risk levels by RT receipt status. Of the patients classified as low-risk, 72.6% received RT, compared with 70.1% of those meeting high-risk criteria ($P = .002$). Table 4 shows RT receipt status by risk level for the entire cohort. Of the patients who received RT, a smaller proportion were classified as high-risk compared with those who did not receive RT (60.9% vs 63.9%; $P = .002$).

Figure 1 demonstrates that for certain regions, rurality and urbanity may have been associated with the receipt of RT. In the choropleth map of model 1, the likelihood of receiving RT regardless of risk level, most areas considered all urban and mostly urban on the east and west coasts have high to medium radiation use. In the choropleth map of model 2, among patients who are considered high risk for recurrence and have received RT, all urban and mostly urban HSAs reveal high to medium radiation use, whereas those considered all rural and mostly rural reveal less RT use. In the choropleth map showing model 3, among patients considered at low risk for recurrence, there is higher radiation use in all urban or mostly urban HSAs in Washington and California. Meanwhile, radiation for those considered at low risk is lower for HSAs on the East Coast in this model. In the choropleth map of Model 5, among patients at low risk for recurrence, radiation usage is medium to high in areas considered all urban and mostly urban.

Findings from the multivariable logistic regression analyses are summarized in Table 5, including ICCs to assess the contribution of regional variation toward the outcomes. Five modeling approaches were used to analyze whether the contribution of region to variation in RT use differed relative to the level of risk for recurrence of the cohort. These analyses may identify patterns of disparity in the use and delivery of RT. Models 1, 2, and 3 are multivariable analyses on the odds of receiving RT and either high or low risk status among all patients in the whole cohort. Models 4 and 5 address 2 different subpopulations of patients. Model 1 provides a benchmark for the odds of receiving RT regardless of risk status. Model 2 addresses whether patients at high risk for local recurrence, for whom RT is highly recommended, are likely to receive RT. Model 4 addresses the odds of being high-risk among patients who have received RT, assessing whether appropriation of RT follows risk level or some other determinant. Model 3 addresses whether patients at low-risk for recurrence, for whom RT is discretionary, are likely to receive RT. Model 5 addresses the likelihood of receiving...
RT among patients considered low-risk. These models work together to address patterns of RT use relative to risk level.

Among the entire cohort, patients in all rural areas had decreased odds of receiving RT compared with the all urban areas (OR, 0.73; \( P < .001 \)) (model 1). This was also true when predicting the odds of being high-risk and receiving RT among all patients (OR, 0.69; \( P < .001 \)). We also observed differences in the odds of treatment among different race and ethnicity subgroups. Black patients (OR, 0.73; \( P = .001 \)) and Asian patients (OR, 0.74; \( P = .004 \)) had lower odds of receiving RT relative to White patients (model 1). Asian patients (OR, 0.72; \( P = .001 \)) and Hispanic patients (OR, 0.76; \( P = .003 \)) also had lower odds of being high-risk and receiving RT among the general cohort (model 2). Patients with \( \geq 2 \) comorbidities had decreased odds of receiving RT (OR, 0.81; \( P = .001 \)) (model 1).

The regional ICC for HSA varied according to the outcome studied (Table 5). The overall ICCs were small, as expected for a binary outcome. An ICC of 0.69; \( P < .001 \)) was observed for the likelihood of receiving RT among all patients regardless of risk level (model 1). The observed ICC was 0.06 for the likelihood of receiving RT among low-risk patients (model 5). However, the ICC decreased to 0.02 in the model, predicting both receipt of RT and being high-risk (model 2). The ICC was the lowest (0.01)

### Table 3 \( \chi^2 \), risk level by RT status

| Risk level          | Received RT, No. (%) | Did not receive RT, No. (%) | \( P \) value |
|---------------------|-----------------------|----------------------------|--------------|
| High risk (n = 8146) | 5704 (70.1)           | 2436 (29.9)                | .002         |
| Low Risk (n = 5036) | 3658 (72.6)           | 1378 (27.4)                |              |
| Overall (N = 13,176)| 9362 (71.1)           | 3814 (28.9)                |              |

**Abbreviation:** RT = radiation therapy.

### Table 4 \( \chi^2 \), RT status by risk level*

| RT status          | High risk (%) | Low risk (%) | \( P \) value |
|--------------------|---------------|--------------|--------------|
| Received (n = 9362)| 5704 (60.9)   | 3658 (39.1)  | .002         |
| Did not receive (n = 3814)| 2436 (63.9) | 1378 (36.1) |              |
| Overall (N = 13,176)| 8140 (61.8)  | 5036 (38.2)  |              |

**Abbreviation:** RT = radiation therapy.

Figure 1 Choropleth maps showing radiation usage and risk levels of each of the five outcomes in tertiles.
Table 5  ORs, 95% CIs, and p values from multivariate analyses are shown for variables associated with 5 outcomes of RT use based on risk level

| Predictor                                      | Model 1: Receiving RT / all | Model 2: High risk and receiving RT / all | Model 3: Low risk and receiving RT / all | Model 4: High-risk / all having received RT | Model 5: Receiving RT / low risk |
|------------------------------------------------|-----------------------------|------------------------------------------|------------------------------------------|---------------------------------------------|---------------------------------|
| Attained diagnosis age, y (SEER)               | OR 0.97 95% CI 0.96-0.98    | P value <.001                            | OR 1.01 95% CI 1.00-1.02                | P value 0.269                              | OR 1.03 95% CI 1.02-1.04       |
| Years of diagnosis                             | OR 0.97 95% CI 0.94-0.99    | P value .016                             | OR 0.9 95% CI 0.88-0.93                 | P value <.001                              | OR 0.88 95% CI 0.86-0.91       |
| Race and ethnicity                              |                             |                                          |                                          |                                              |                                |
| Black vs White                                 | OR 0.73 95% CI 0.62-0.88    | P value .001                             | OR 0.95 95% CI 0.80-1.12                | P value .536                               | OR 1.2 95% CI 1.07-1.38       |
| Hispanic vs White                              | OR 0.91 95% CI 0.75-1.11    | P value .346                             | OR 0.76 95% CI 0.63-0.91                | P value .001                               | OR 0.75 95% CI 0.60-0.92       |
| Asian vs White                                 | OR 0.74 95% CI 0.61-0.91    | P value .004                             | OR 0.72 95% CI 0.59-0.87                | P value .001                               | OR 1.1 95% CI 0.81-1.50       |
| Other vs White                                 | OR 0.67 95% CI 0.42-1.07    | P value .091                             | OR 0.68 95% CI 0.42-1.08                | P value .105                               | OR 0.82 95% CI 0.46-1.43       |
| SES                                           |                             |                                          |                                          |                                              |                                |
| Q2 vs Q1                                       | OR 0.96 95% CI 0.84-1.08    | P value .477                             | OR 1.13 95% CI 1.01-1.27                | P value .039                               | OR 1.24 95% CI 1.08-1.42       |
| Q3 vs Q1                                       | OR 0.9 95% CI 0.79-1.02     | P value .112                             | OR 1.06 95% CI 0.94-1.19                | P value .337                               | OR 1.19 95% CI 1.03-1.36       |
| Q4 vs Q1                                       | OR 0.88 95% CI 0.77-1.00    | P value .055                             | OR 1.03 95% CI 0.91-1.15                | P value .664                               | OR 1.14 95% CI 0.99-1.31       |
| Q5 vs Q1                                       | OR 0.94 95% CI 0.82-1.08    | P value .39                              | OR 1.08 95% CI 0.96-1.22                | P value .215                               | OR 1.18 95% CI 1.02-1.36       |
| Education                                      |                             |                                          |                                          |                                              |                                |
| Q2 vs Q1                                       | OR 0.96 95% CI 0.85-1.09    | P value .548                             | OR 1.02 95% CI 0.91-1.14                | P value .776                               | OR 1.06 95% CI 0.93-1.22       |
| Q3 vs Q1                                       | OR 0.99 95% CI 0.87-1.13    | P value .925                             | OR 1.03 95% CI 0.91-1.15                | P value .657                               | OR 1.06 95% CI 0.92-1.22       |
| Q4 vs Q1                                       | OR 0.97 95% CI 0.86-1.11    | P value .689                             | OR 1.12 95% CI 1.00-1.26                | P value .052                               | OR 1.22 95% CI 1.06-1.40       |
| Q5 vs Q1                                       | OR 0.97 95% CI 0.85-1.10    | P value .627                             | OR 1.19 95% CI 1.05-1.34                | P value .005                               | OR 1.33 95% CI 1.15-1.54       |
| Rurality                                       |                             |                                          |                                          |                                              |                                |
| Mostly urban vs all urban                      | OR 0.85 95% CI 0.77-0.94    | P value .002                             | OR 0.95 95% CI 0.86-1.04                | P value .232                               | OR 1.03 95% CI 0.92-1.15       |
| Mostly rural vs all urban                      | OR 0.96 95% CI 0.82-1.13    | P value .647                             | OR 0.92 95% CI 0.80-1.06                | P value .26                                | OR 0.91 95% CI 0.77-1.08       |
| All rural vs all urban                         | OR 0.73 95% CI 0.62-0.86    | P value <.001                            | OR 0.69 95% CI 0.59-0.80                | P value <.001                              | OR 0.75 95% CI 0.63-0.90       |
| Charlson Comorbidity Index                     |                             |                                          |                                          |                                              |                                |
| 1 Comorbidity vs none                          | OR 0.92 95% CI 0.83-1.01    | P value .067                             | OR 0.95 95% CI 0.87-1.03                | P value .219                               | OR 0.97 95% CI 0.88-1.07       |
| ≥2 Comorbidities vs none                       | OR 0.81 95% CI 0.72-0.91    | P value .001                             | OR 0.84 95% CI 0.75-0.94                | P value .003                               | OR 0.99 95% CI 0.87-1.12       |

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Table 5 (Continued)

| Predictor                        | Model 1: Receiving RT / all | Model 2: High risk and receiving RT / all | Model 3: Low risk and receiving RT / all | Model 4: High-risk / all having received RT | Model 5: Receiving RT / low risk |
|----------------------------------|-----------------------------|--------------------------------------------|------------------------------------------|---------------------------------------------|---------------------------------|
|                                  | OR    | 95% CI | P value | OR    | 95% CI | P value | OR    | 95% CI | P value | OR    | 95% CI | P value | OR    | 95% CI | P value |
| Tumor size, cm                   |       |        |         |       |        |         |       |        |         |       |        |         |       |        |         |
| 2-5 vs <2                        | 0.87  | 0.78-0.97 | .01       | 0.85  | 0.77-0.93 | .001   | 1.06  | 0.95-1.18 | .284  | 0.87  | 0.77-0.98 | .024  | 1.02  | 0.85-1.22 | .843  |
| >5 vs <2                         | 0.84  | 0.43-1.66 | .618     | 1.32  | 0.70-2.50 | .389   | 0.51  | 0.21-1.23 | .131  | 2.03  | 0.80-5.15 | .136  | 0.41  | 0.13-1.32 | .136  |
| Tumor grade                      |       |        |         |       |        |         |       |        |         |       |        |         |       |        |         |
| Moderately differentiated vs     | 1.15  | 1.05-1.25 | .003     | 1.04  | 0.96-1.13 | .31    | 1.09  | 1.00-1.19 | .056  | 0.96  | 0.87-1.06 | .423  | 1.14  | 0.99-1.31 | .069  |
| poorly differentiated             |       |        |         |       |        |         |       |        |         |       |        |         |       |        |         |
| Poorly differentiated vs          | 1.39  | 1.24-1.56 | <.001    | 1.93  | 1.74-2.14 | <.001  | 0.59  | 0.53-0.67 | <.001 | 2.1   | 1.84-2.39 | <.001 | 1.33  | 1.07-1.65 | .009  |
| differentiated                    |       |        |         |       |        |         |       |        |         |       |        |         |       |        |         |
| Undifferentiated vs               | 0.97  | 0.53-1.79 | .93      | 1.53  | 0.86-2.71 | .145   | 0.5   | 0.23-1.07 | .075  | 2.27  | 1.01-5.11 | .048  | 1.93  | 0.40-9.35 | .415  |
| poorly differentiated             |       |        |         |       |        |         |       |        |         |       |        |         |       |        |         |
| Unknown vs differentiated         | 0.82  | 0.68-0.99 | .043     | 1.21  | 1.01-1.44 | .04    | 0.63  | 0.51-0.78 | <.001 | 1.58  | 1.25-2.00 | <.001 | 0.73  | 0.53-1.02 | .066  |
| Random effects                    |       |        |         |       |        |         |       |        |         |       |        |         |       |        |         |
| ICC                              | 0.05  |          |         | 0.02  |          |         | 0.02  |          |         | 0.01  |          |         | 0.06  |          |         |
| Total HSA, No.                   | 187   |          |         | 187   |          |         | 187   |          |         | 184   |          |         | 183   |          |         |
| Cohort, No.                      | 13,176 |        |         | 13,176 |        |         | 13,176 |        |         | 9362  |        |         | 5036  |        |         |

*Abbreviations: CI = confidence interval; HSA = Health Service Area; ICC = interclass correlation coefficient; OR = odds ratio; Q = quintile; RT = radiation therapy; SEER = Surveillance, Epidemiology, and End Results Program; SES = socioeconomic status.*
for the model predicting being high-risk among patients who had all received RT (model 4).

Discussion

We used the SEER-Medicare database to study the receipt of radiation therapy after breast-conserving surgery according to recurrence risk level and to assess the contribution of regional variation in its use. We found that the likelihood of receiving RT did not vary by recurrence risk level. In our study, Black and Asian race were both associated with lower odds of receiving RT after controlling for other covariates listed in Table 5. We also found that patients living in all rural areas had lower odds of receiving RT compared with patients living in all urban areas. Furthermore, we found that there was regional variability in RT receipt.

Our finding that race and ethnicity and rurality were associated with decreased odds of receiving RT corroborates other examples of racial and ethnic disparities in cancer care delivery and outcomes demonstrated in existing literature.19–21 An earlier study by Sail et al showed that Black women had lower odds than White women of receiving adjuvant chemotherapy or radiation after breast-conserving surgery.22 Our study, using more recent data, demonstrated that this disparity remained and was of similar magnitude as that noted by Sail.

Modeling of regional variation by including HSAs demonstrated that regional biases were more apparent when RT was discretionary (ie, among the low-risk patients). Our study showed that patients who received RT did not necessarily have features that increase the risk of cancer recurrence; in fact, high-risk patients represented a lower proportion of those who received RT versus those who did not. Additionally, we observed that a greater proportion of low-risk patients received RT compared with those who were high-risk. The choropleth maps suggest that urban areas have the greatest capacity for radiation and that rurality has an effect on receipt of RT regardless of risk status. Even for those patients in whom RT is recommended, there are regional differences in the receipt of RT. The maps also demonstrate that patients considered low-risk but who receive RT tend to live in urban areas and that many HSAs considered either “all urban” or “mostly urban” exhibit greater radiation use among patients considered low-risk, corroborating our modeling results.

Evidence that the likelihood of receiving RT seems to be dictated by paradigms other than patient risk level suggests that other determinants of RT use may be more influential on the receipt of treatment. Likely examples could include referrals to RT and to a radiation oncologist as well as the patient’s access to RT facilities, which most likely differ based on region and urbanity.

Our study was conducted using the SEER-Medicare linked data, which provided us with a large, population-based cohort and allowed us to use HSAs to analyze regional variability of use of RT among our cohort. However, our study is limited by the retrospective nature of claims data. Our cohort only includes patients who were aged 66 to 79 years, were enrolled in Medicare, and who lived in a SEER region. As such, the results may not be generalizable to other populations. However, although absolute values may differ among younger patients, relative differences between regions would likely be similar. Treatment patterns and regional patterns observed may have changed over time, which would not be reflected in the data. Claims data do not include information on physician-patient communication or patient preferences, which could influence treatment decision making. Lastly, claims data do not provide the same granular clinical insight of a medical record chart review, but they are directly correlated with the costs of treatment, which is salient in our current health care climate.

Disparities in breast cancer treatment by region, age, and race and ethnicity are known to have significant effects on recurrence and survival rates. The greatest contributing factors to these differences in outcomes are not yet known. Understanding regional patterns of RT delivery will help identify areas that may benefit from intervention and provide the basis for actionable improvements in the US health care delivery system. Future work must be directed toward identifying the root causes of these observed regional disparities by performing analyses on variables of interest, such as the density of radiation facilities and specialists per HSA.

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