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Structural/organizational characteristics of health services partly explain racial variation in timeliness of radiation therapy among elderly breast cancer patients

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Abstract

Observed racial/ethnic disparities in the process and outcomes of breast cancer care may be explained, in part, by structural/organizational characteristics of health care systems. We examined the role of surgical facility characteristics and distance to care in explaining racial/ethnic variation in timing of initiation of guideline-recommended radiation therapy (RT) after breast conserving surgery (BCS). We used Surveillance Epidemiology and End Results-Medicare data to identify women ages 65 and older diagnosed with stages I–III breast cancer and treated with BCS in 1994–2002. We used stepwise multivariate logistic regression to examine the interactive effects of race/ethnicity and facility profit status, teaching status, size, and institutional affiliations, and distance to nearest RT on timing of RT initiation, controlling for known covariates. Among 38,574 eligible

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women who received BCS, 39% received RT within 2 months, 52% received RT within 6 months, and 57% received RT within 12 months post-diagnosis, with significant variation by race/ethnicity. In multivariate models, women attending smaller surgical facilities and those with on-site radiation had higher odds of RT at each time interval, and women attending governmental facilities had lower odds of RT at each time interval ($P < 0.05$). Increasing distance between patients' residence and nearest RT provider was associated with lower overall odds of RT, particularly among Hispanic women ($P < 0.05$). In fully adjusted models including race-by-distance interaction terms, racial/ethnic disparities disappeared in RT initiation within 6 and 12 months. Racial/ethnic disparities in timing of RT for breast cancer can be partially explained by structural/organizational health system characteristics. Identifying modifiable system-level factors associated with quality cancer care may help us target policy interventions that can reduce disparities in outcomes.

Keywords

Health services organization; Breast cancer care quality; Timing; SEER-Medicare; Distance to care; Disparities

Introduction

Breast cancer treatment quality and outcomes vary widely across providers and geographic regions within the US [1–14]. Minority and elderly women appear to be at particularly high risk for poor quality care [7, 15, 16]. Overall, breast cancer trends during the past 25–30 years have shown general improvements in guideline-concordant care and mortality [15]. However, aggregate improvements in quality of cancer care may mask persistent or growing differences in important sub-populations, including racial/ethnic minorities.

Racial/ethnic disparities in breast cancer quality and outcomes are often attributed to socio-economic status (SES), co-morbid conditions, and biological tumor characteristics [17–21]. However, observed racial/ethnic disparities may be explained by organizational/structural characteristics of health systems, such as distance from patients' residence to oncology care providers [22], facility size and patient volume [6, 14], facility ownership/control, academic teaching center status [5, 6, 12], or National Cancer Institute (NCI) Comprehensive Cancer Center designation or other professional affiliations [1, 2, 23]. It is unclear exactly how multiple characteristics of health care systems and patient demographics interact to predict receipt of high-quality breast cancer care.

The existing literature demonstrates that racial/ethnic disparities exist in overall receipt of radiation therapy (RT) after receiving breast conserving surgery (BCS) [4, 7, 16, 24]. We extend this literature by examining the interactive effect of relationships between race/ethnicity and structural/organizational characteristics of health care systems (i.e., distance to RT providers and surgical facility ownership/control, academic teaching center status, NCI Comprehensive Cancer Center designation, American College of Surgeons Oncology Group (ACoSOG) affiliation, and access to RT services on-site) on timing of guideline-concordant initiation of RT for elderly women who received BCS [25].

Methods

Conceptual model

Organizational and diffusion of innovations theories suggest that substantially different institutional cultures exist within different types of health organizations [26–28] and may affect delivery of high-quality, evidence-based practices [28]. Characteristics of local communities (e.g., population SES, racial/ethnic composition) often influence the types of organizations that locate in particular settings, which may lead to differential access/ availability of care to certain sub-populations [29, 30]. For example, racial/ethnic groups may prefer hospitals that recognize and address language or literacy barriers by employing translators; facilities that can afford to provide such services likely have different organizational characteristics from those facilities that do not. Previous studies often assumed that organizational factors affect quality of care via direct pathways only. A conceptual framework (Fig. 1), adapted from Bickell et al. [31], suggests that quality of care (i.e., timing of RT after BCS) is a product of interacting patient-, provider-, and health system-level factors. That is, patient factors, such as race/ethnicity and SES, affect care through both direct and indirect and/or mediating pathways. Similarly, health systems' structural/organizational characteristics may independently influence high-quality care, but also may do so through interactions with patient characteristics. The conceptual framework considers the inter-connectedness of various units within health systems and the larger community/society.

Data source and patient population

We linked Surveillance, Epidemiology, and End Results (SEER) registry data from 1994 to 2002 to Medicare claims through 2007. SEER registries represent ~26% of the US population, and Medicare is the primary insurer for 97% of Americans ages 65 and older [32]. Patient records from 16 SEER registries (excluding the Alaska SEER registry, which is limited to Native Americans) were used. The patient entitlement and diagnosis summary file provided clinical, demographic, geographic, and census-derived aggregate socio-economic information. Medicare claims were used to ascertain details about surgery and RT services, as well as distance to healthcare providers. The NCI hospital file [33] provided structural/ organizational characteristics about surgical providers, including facility size (i.e., number of beds), facility type/ownership (i.e., for-profit/private, non-profit, governmental), academic teaching center status, NCI Comprehensive Cancer Center designation, ACoSOG affiliation, and the presence of on-site radiation services.

We included female, Medicare beneficiaries living in SEER regions who: were diagnosed with stages I–III primary breast cancer, were continuously enrolled in Medicare parts A and B from 1-year pre- to 1-year post-diagnosis, and received BCS (according to SEER or Medicare claims). We excluded beneficiaries who were male, enrolled in managed care only (due to our inability to assess quality of care), had a racial/ethnic background other than non-Hispanic white, non-Hispanic black, and Hispanic (due to insufficient numbers for analyses) [34], had end-stage renal disease, received anti-cancer treatment before the index diagnosis date, or had an additional cancer diagnosis within 1 year of the index breast cancer diagnosis (Fig. 2). We made clinical exclusions specific to each time period (i.e., 2-, 6-, and

12-months post-diagnosis); women who received mastectomy subsequent to BCS (because adherence to the RT guideline may no longer be relevant for these patients), received chemotherapy (because receipt of chemotherapy leads to clinically valid delays in RT [35, 36]), or who died during the relevant time period were excluded.

Dependent variable

The American Society of Clinical Oncology (ASCO)/National Comprehensive Cancer Network (NCCN) quality metric for post-BCS RT specifies that the patient must begin RT within 12 months of diagnosis [37]. However, given evidence that earlier initiation of RT may impact recurrence-free survival [35, 38], we also examined initiation of RT at 2- and 6-months post-diagnosis. Timing of initial receipt of RT was coded as a binary variable within each time interval. Relevant codes were taken from the Healthcare Common Procedure Classification System and the International Statistical Classification of Diseases and Related Health Problems, 9th revision, clinical modification (available upon request).

Independent variables

The main independent variables were race/ethnicity (measured categorically using SEER data [34]), characteristics of health facility where women received surgery (i.e., type/ownership, size, NCI Comprehensive Cancer Center designation, ACoSOG affiliation, teaching status, and the presence of on-site radiation), and distance to nearest RT facility. Structural/organizational variables were consistent with our conceptual model and existing evidence of provider and health system factors influencing quality of cancer care [5, 6, 12, 22, 23, 39–44]. Characteristics of the facilities where women received primary surgery were identified from the NCI hospital file, using facility data from the time period closest to the relevant claims date [33]. To calculate distance to the nearest radiation facility, we identified all Medicare beneficiaries treated for breast cancer in SEER regions from 1994 to 2003 and all providers/facilities for which RT claims were filed. From this information, we created a master file of all RT providers who had treated Medicare patients over the study period and their associated zip codes. Using a minimum distance algorithm based on Cartesian products of all latitude and longitude of zip code centroids, we determined shortest distance to the nearest radiation facility for each woman [45]. Straight-line distances are a reasonable proxy for travel time and geographic access to care for actual time patients spent traveling to health providers [45]. Distance to nearest RT provider was categorized into zero distance (i.e., nearest RT provider was located in the same zip code as patient residence) and quartiles (by distance measured in miles).

Covariates

Review of the breast cancer literature revealed several important potential confounders that influence cancer treatment and, as such, were included in multivariate models. These included age, co-morbidities, and tumor biology (i.e., stage of disease, lymph node status, hormone receptor status, and histologic grade), which affect physician prescribing patterns and suitability of patients for invasive therapeutic treatment. SES, which affects access to care and healthcare utilization behavior [44, 46, 47], was measured by State-Buy-In months during the study period (a proxy for low income status [34]) and by zip code-level median income and education. In addition, given evidence of rural/urban variation in cancer treatment, we included rural/urban patient residence, defined as: metropolitan (250,000 to >1 million), urban (2,500–250,000), and (<2,500/county). Familial and social support, which are predictors of receipt of and adherence to anti-cancer therapeutic regimens [48], were measured using patient-level marital status and zip code-level racial/ethnic diversity. Finally, year of diagnosis dummy variables were included as covariates to adjust for cohort effects and secular changes in healthcare policies and practices over time.

Statistical analysis

Unadjusted odds ratios (OR) from naïve models were first used to estimate the effect of race/ethnicity on receipt of post-BCS RT within 2-, 6-, and 12-months post-diagnosis. We examined the distribution of organizational/structural health services characteristics across racial/ethnic groups using χ^2 tests or *t* tests for categorical and continuous outcomes, respectively [49, 50].

Multivariate logistic regressions for each time period were specified in a stepwise fashion, first adding patient clinical and demographic covariates to the naïve model, then structural/organizational health services variables, and finally interactions of race/ethnicity and distance to RT providers. This strategy creates a "fully adjusted" model (excluding women who died or received chemotherapy or mastectomy in each relevant time period). Functional forms of independent variables and each independent variable's predictive and confounding power were assessed by examining changes in the magnitude or significance of the main effect of race/ethnicity, changes in the overall likelihood ratio test (LRT) statistic, and Wald test statistics for individual terms with each model iteration [49, 51]. Wald tests were also used to test the joint significance of variable constructs (e.g., the group of dummy variables for year of diagnosis) [52]. Modification of the main effect of race/ethnicity was assessed by examining interaction terms between race/ethnicity and structural/organizational health services characteristics, using the "margins" and "lincom" commands to estimate marginal effects and statistical significance in Stata version 11 (Stata Corporation, College Station, Texas). Only race/ethnicity-by-distance interactions indicating differential effects of distance to RT providers according to racial/ethnic group were included in final fully adjusted models. The 5% level of significance was used to assess predictive power of each individual term, and a change threshold of 10% was used to assess confounding and modification potential of independent variables [51]. Using the "collin" command in Stata, we found multicollinearity among variables to be a non-issue. We also assessed potential correlation across observations in regions/registries for time to RT and found little evidence of clustering by region/registry (intraclass correlation: 0.02; standard error: 0.00879). Due to inherent heteroskedasticity in the general equation, we corrected standard errors using Huber White robust standard errors for all regression models [52].

Necessary human subjects approval for this study was granted by the UNC Institutional Review Board (IRB), and findings were reviewed by SEER-Medicare officials for confidentiality assurances.

Results

Descriptive characteristics of the 38,574 women who met eligibility criteria are summarized in Table 1. Mean age at diagnosis was 75.6 years, and 90% were non-Hispanic white. Whereas only 39% of women treated with BCS received RT within 2 months of diagnosis, 52% and 57% received RT within 6 and 12 months, respectively. As we excluded women who died or received subsequent mastectomy or chemotherapy during each relevant time period, these findings indicate significant underuse overall. Non-Hispanic black women experienced the greatest delays in RT initiation, were more likely to have stage III disease, positive lymph nodes, and greater co-morbidity, and less likely to have hormone receptor positive tumors. Both black and Hispanic women were more often lower income compared to white women.

Bivariate analyses identified significant racial/ethnic differences in the types of surgical facilities used, as well as geographical proximity to surgery and RT providers (Table 2). For example, black women were more likely to receive surgery at a teaching/academic health center (63% vs. 47% of white women and 37% of Hispanic women, $P < 0.001$), or a facility where radiation services were offered (85% vs. 77% of white women and 73% of Hispanic women, $P < 0.001$). Hispanic women, on the other hand, were more likely to attend for-profit/private health care facilities (15% compared with 7% of white women and 8% of black women, $P < 0.001$). Among women who initiated RT, the average distance traveled to that RT facility ranged from 12.3 to 17.3 miles.

Comparisons of logistic regression models across all three time intervals indicated that racial/ethnic disparities in RT initiation were attenuated with inclusion of structural/organizational health services variables (Tables 3, 4, 5). For example, naïve models indicated that the ORs for black women relative to white women for initiating RT at 2 months were 0.46 ($P < 0.01$; Table 3); at 6 months, 0.58 ($P < 0.01$; Table 4); and at 12 months, 0.62 ($P < 0.01$; Table 5). Inclusion of patient-level demographic and clinical variables somewhat attenuated these racial differences; however, in fully adjusted models predicting receipt of RT within 6 months (Table 4) and 12 months (Table 5), the effect of black race was no longer a significant predictor. Rather, distance to RT providers, surgical facility characteristics, and other patient-level variables explained more of the variation in timing of RT initiation. The naïve model for RT at 2 months indicated that Hispanic women had 0.75 lower odds of initiating RT at 2 months compared to white women ($P < 0.01$; Table 3). However, the fully adjusted model revealed that distance to RT providers was an important modifier: Hispanic women living furthest away from RT providers were least likely to initiate RT at 2 months (Table 3). This finding was consistent across time periods in fully adjusted models at 6 months (Table 4) and 12 months (Table 5). ORs were significant and positive for Hispanic women living in a zip code where the nearest RT provider was located in that same zip code, whereas Hispanic women living furthest away from a RT provider (specifically, in RT distance quartiles 3 and 4) had much lower odds of receiving RT at 2, 6, and 12 months ($P < 0.05$). Even among non-Hispanic white women, living furthest away from a RT provider (quartiles 3 and 4) was associated with lower odds of RT initiation within 6 months (OR_{Q3}: 0.81, $P < 0.01$; OR_{Q4}: 0.79, $P < 0.01$; Table 4) and 12 months

(OR_{Q3}: 0.79, $P < 0.01$; OR_{Q4}: 0.79, $P < 0.01$; Table 5), relative to white women who had access to a RT provider in the same zip code where they lived.

In general, inclusion of surgical facility characteristics changed the effect size and significance of other variables, notably race/ethnicity. And surgical facility characteristics were statistically significant predictors of timing of RT initiation. Specifically, at 2 months, attending a private/for-profit surgical facility was associated with higher odds of initiation of RT (OR: 1.35, $P < 0.01$), as was attending a facility with on-site RT (OR: 1.35, $P < 0.01$) and a smaller facility (OR: 1.08, $P < 0.05$). Attending a surgical facility designated as a NCI Comprehensive Cancer Center or government-owned was associated with lower odds of RT initiation (OR: 0.57, $P < 0.01$; OR: 0.89, $P < 0.05$) (Table 3). These findings, with the exception of the effects of private/for-profit status and NCI Comprehensive Cancer Center designation, were consistent at 6 and 12 months (Tables 4, 5). Other covariates behaved generally in expected ways.

Discussion

Using data from SEER-Medicare, we show that structural/organizational characteristics of health services are significant independent predictors of RT initiation at 2, 6, and 12 months and partially explain racial/ethnic variation in RT timing. Structural/organizational predictors of timing of RT included distance to RT providers, and the presence of on-site radiation services, type/ownership, and size of the facility where women received surgery. Increasing distance to RT providers generally was associated with lower odds of initiation of RT at each time interval examined, with greater evidence of access burden for Hispanic women. This is consistent with previous research suggesting that transportation burden and geographic access are problematic for elderly women seeking health care; [22, 53] to the best of our knowledge, this is the first study to document greater distance-related accessibility burden for Hispanic women compared to other women. The lack of consistent distance to care effect for non-Hispanic black women may be due to the majority of black women in our sample living within 3 miles of an RT provider. Our finding that government hospitals and larger hospitals were associated with delays in RT initiation may be related to those facilities being located in metropolitan areas where care may be more fragmented (especially if these facilities are safety net providers treating a lower income patient population with more complex health care needs). ACoSOG affiliation, NCI Comprehensive Cancer Center designation, and teaching status of the surgical facility, on the other hand, were less predictive of treatment quality and health outcomes in the absence of other structural and organizational variables [1, 2, 5, 12]. These findings may be explained by SEER-Medicare sampling. Comparing health services characteristics by racial/ethnic group, it is clear from bivariate analyses (Table 2) that significant differences existed in the types of surgical facilities used by racial/ethnic groups. In this study, black women more often received surgery at NCI-designated Comprehensive Cancer Centers, ACoSOG-affiliated facilities, and teaching/academic health centers (Table 2). Although SEER-Medicare data were designed to reflect diverse geographic communities and racial/ethnic groups [32], the majority of black women live in metropolitan areas (e.g., Detroit, Atlanta), where larger hospitals, and more NCI Comprehensive Cancer Centers and academic/teaching hospitals, exist. As such, our study may not be generalizable to all minority populations living in the US.

Our overall finding that receipt of RT remains suboptimal is consistent with previous literature [7, 15, 16, 19, 54, 55]. Importantly, the relationships among age, adjuvant therapy, and clinical guideline development are complex and somewhat controversial. Thus, many women delay initiation of RT for clinically valid reasons. For example, among women 70 years and older with stage I, ER-positive breast cancer, RT may be safely omitted after lumpectomy when women are receiving tamoxifen [56]. Although results from this trial were published after our study period, it is possible that practice patterns for older women with early, ER-positive breast cancer may have begun to change in light of this new evidence.

Our study has several limitations. First, we lack information regarding hormonal therapy, an important therapeutic option which may affect treatment planning [32]. Second, our findings are restricted to women 65 years and older who are not enrolled in Medicare managed care plans; younger women and those enrolled in managed care plans may be healthier, and thus, treatment experiences may be different. Third, we lack precise measures of SES and supplemental private health insurance. We tried to account for these factors by including measures for State-Buy-In and neighborhood (zip-code level) education, income, and racial/ethnic composition as a measure of local social support [53]. Fourth, we used straight-line distance to RT providers using zip code-to-zip code centroids. Although there are other strategies to assess geographic access, straight-line distance is highly correlated with travel time and, by extension, transportation burden [45]. Finally, possible omitted variables may exist, including information about patient health-seeking behavior, trust in the health care system, and provider intent. These factors may help explain initiation of RT, but investigating these issues fully requires different methodologies beyond the scope of this study.

Despite these limitations, our study has several important strengths. First, by examining Medicare beneficiaries, we effectively controlled for access to insurance coverage. Accordingly, we were able to explore whether characteristics of the health system itself potentially could be used to narrow differences in quality of care. In addition, we examined initiation of RT at 2, 6, and 12 months, rather than only at 1 year as specified in the ASCO/NCCN quality metric. Using more narrow time periods is important in light of studies that have shown improved outcomes with earlier initiation of RT [57–59]. Although the ASCO/NCCN panels relaxed the timing component of the quality metric to allow for administration and sequencing of multiple anti-cancer treatments [37], given the controversy over the optimal timing of initiation of RT, and considering that we have shown significant racial/ethnic differences in timing of initiation of RT, it may be that earlier initiation of RT is particularly important for vulnerable breast cancer patients. Given these strengths, our findings suggest that interventions should consider targeting facilities performing less well, such as government hospitals and surgical facilities without on-site RT services available. In addition, since we have shown distance to RT providers influences timing of RT initiation, interventions that address barriers to care related to distance may lead to more guideline-concordant use of RT among women healthy enough to undergo treatment. For example, offering transportation options to Hispanic women in remote areas may improve breast cancer outcomes. Recognizing the importance of such health system level variables in the context of significant variation in breast cancer treatment quality may help policymakers, clinicians, and other stakeholders to better identify and treat women at risk for suboptimal care and reduce observed disparities in outcomes.

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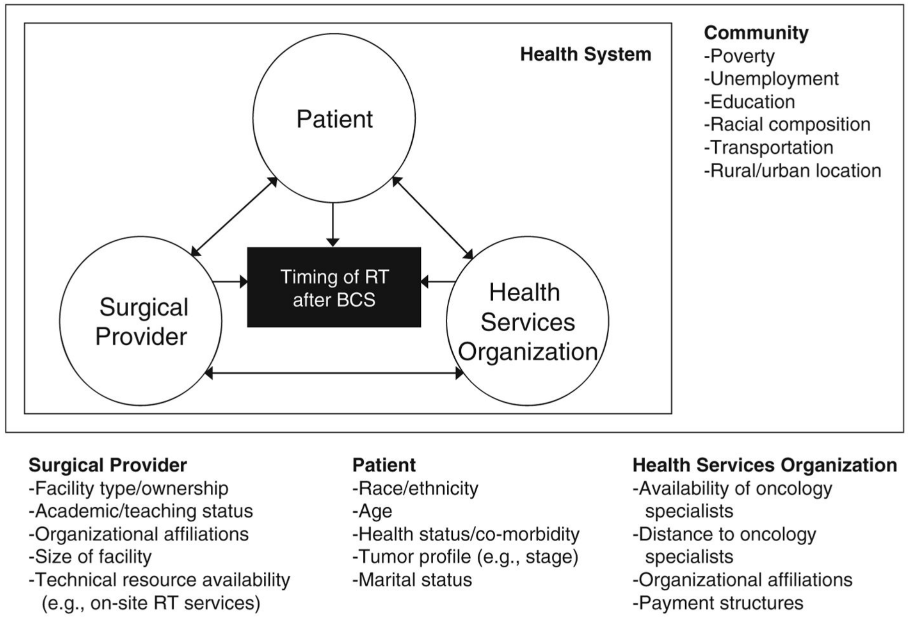

Fig. 1.

Conceptual framework, adapted from Bickell et al. [31]

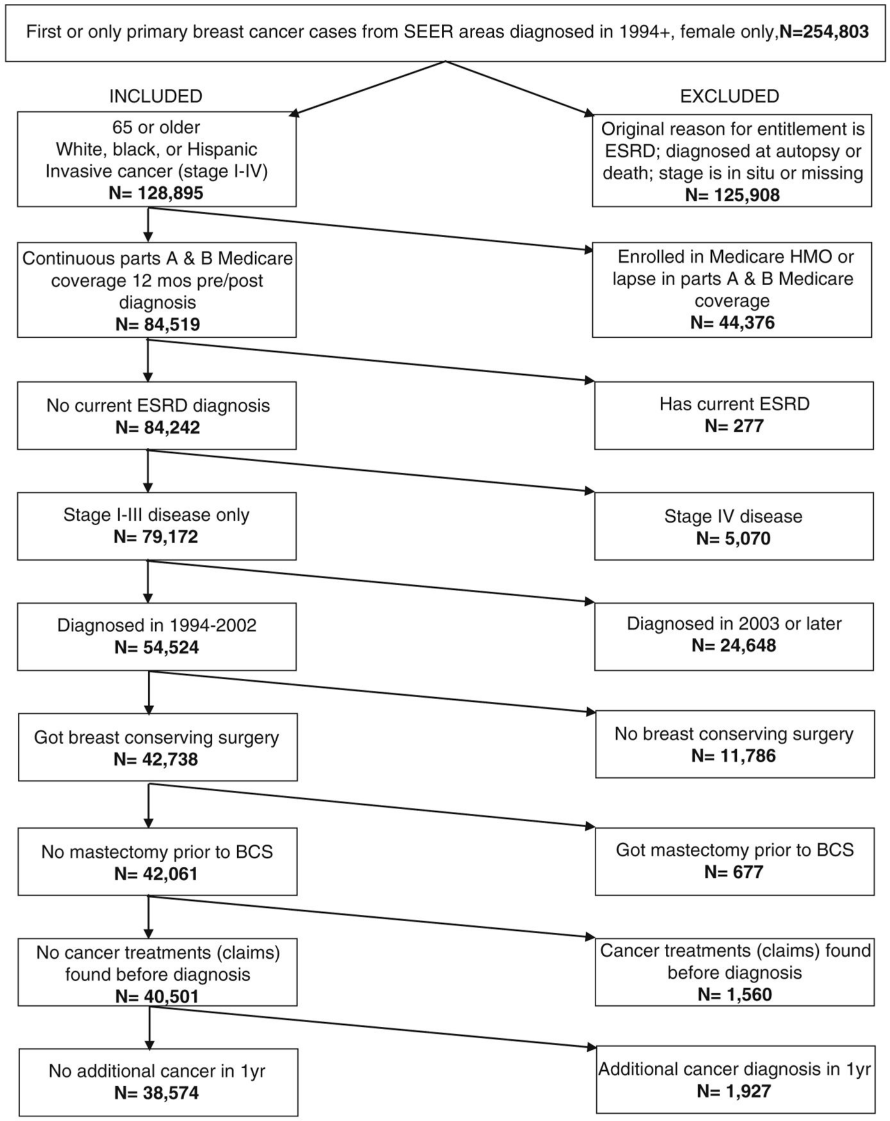

Fig. 2.

Sample size diagram based on inclusion/exclusion criteria. *BCS* breast conserving surgery, *ESRD* end-stage renal disease, *HMO* health maintenance organization

Table 1

Descriptive statistics of full SEER-Medicare patient sample who received BCS

Patient characteristics	Proportion or mean			
	Overall (*N* = 38,574)	Non-Hispanic white (*N* = 34,965)	Non-Hispanic black (*N* = 2,273)	Hispanic (*N* = 1,336)
Age (years)	75.6	75.7	75.2	74.4
Married	43.5%	45.0%	24.3%	39.3%
Low income	16.5%	13.5%	44.6%	49.4%
Resides in metro area	85.1%	84.3%	94.8%	89.4%
Resides in urban area	13.3%	13.9%	5.0%	10.2%
Resides in rural area	1.6%	1.8%	0.2%	0.4%
Diagnosed in 1994	8.6%	8.6%	8.7%	6.8%
Diagnosed in 1995	8.8%	8.8%	8.9%	9.0%
Diagnosed in 1996	8.5%	8.5%	8.6%	8.4%
Diagnosed in 1997	8.8%	8.8%	8.3%	9.1%
Diagnosed in 1998	8.5%	8.5%	8.7%	7.7%
Diagnosed in 1999	8.9%	8.9%	7.9%	9.0%
Diagnosed in 2000	15.9%	15.8%	17.7%	16.8%
Diagnosed in 2001	16.2%	16.3%	15.7%	16.6%
Diagnosed in 2002	15.8%	15.8%	15.5%	16.5%
Stage I	63.5%	64.5%	52.3%	56.4%
Stage II	33.0%	32.3%	41.5%	38.5%
Stage III	3.5%	3.2%	6.1%	5.1%
ER+	70.7%	71.8%	56.8%	66.2%
PR+	58.0%	59.0%	45.2%	54.3%
NCI co-morbidity score	0.26	0.25	0.41	0.33
Node positive	19.0%	18.5%	23.8%	22.8%
Node status missing	24.2%	24.1%	26.9%	21.3%
Receipt of RT after BCS				
RT in 2 months[a]	38.7%	59.1%	40.3%	51.5%
RT in 6 months[b]	52.1%	75.9%	64.3%	77.1%
RT in 12 months[c]	56.7%	77.3%	67.3%	78.4%

BCS breast conserving surgery, *ER* estrogen receptor, *PR* progesterone receptor, *NCI* National Cancer Institute, *RT* radiation therapy

[a]Limited to sub-sample who did not receive subsequent mastectomy, chemotherapy, or die during that time period (2-months post-diagnosis)

[b]Limited to sub-sample who did not receive subsequent mastectomy, chemotherapy, or die during that time period (6-months post-diagnosis)

[c]Limited to sub-sample who did not receive subsequent mastectomy, chemotherapy, or die during that time period (12-months post-diagnosis)

Table 2

Bivariate comparisons of health system organizational factors by race/ethnicity

Characteristics of surgical facility	Proportion or mean			*P* value (from χ^2 test or *t* test)
	Non-Hispanic white	Non-Hispanic black	Hispanic	
Type/ownership				
For-profit/private	6.7%	7.9%	15.3%	< 0.001
Non-profit/voluntary	78.9%	79.9%	70.9%	< 0.001
Government	14.4%	12.2%	13.9%	0.019
NCI Comprehensive Cancer Center	2.4%	10.7%	3.1%	< 0.001
ACoSOG affiliated	23.8%	34.8%	16.2%	< 0.001
Teaching/academic facility	47.1%	63.3%	37.6%	< 0.001
On-site RT services offered	77.1%	84.6%	73.1%	< 0.001
Number of beds	358.4	486.2	300.3	< 0.001[a] < 0.001[b]
Relational factors/access to care				
Nearest radiation facility (miles)	2.81	1.84	2.80	< 0.001[a] 0.969[b]
Nearest radiation facility is located in same zip code as patient residence	21.1%	22.7%	17.9%	0.003
Facility where patient received BCS is located in same zip code as patient residence	17.3%	13.4%	17.5%	< 0.001
Average distance traveled for BCS (miles)	14.9	10.5	12.9	0.001[a] 0.249[b]
Average distance traveled to radiation facility, among those who received RT (first incidence of use) (miles)	17.3	12.3	15.3	0.041[a] 0.490[b]

ACoSOG American College of Surgeons Oncology Group, *NCI* National Cancer Institute, *RT* radiation therapy, *BCS* breast conserving surgery

[a] Two-sample *t* tests between white and black groups

[b] Two-sample *t* tests between white and Hispanic groups

Table 3

Comparative logistic regression models for receipt of RT within 2-months post-diagnosis, by race/ethnicity, among women who received BCS (excluding those who died or received chemotherapy or mastectomy during that 2-month interval)

Independent variables	ORs reported with statistical significance			
	Naive model	**Adjusted model without health services variables**	**Adjusted model with health services variables**	**Fully adjusted model with health services variables and interactions**
Race/ethnicity (reference: non-Hispanic white)				
Non-Hispanic black	**0.46** **	**0.56** **	**0.60** **	**0.60** **
Hispanic	**0.75** **	**0.83** *	**0.83** *	**1.50**
Structural/organizational health services variables				
Interactions (reference: white, nearest RT provider in patient's same zip code)				
Black × RT distance Q1				0.90
Black × RT distance Q2				0.56 *
Black × RT distance Q3				0.85
Black × RT distance Q4				0.62
Hispanic × RT distance Q1				1.08
Hispanic × RT distance Q2				0.42 **
Hispanic × RT distance Q3				1.39
Hispanic × RT distance Q4				0.38 **
Distance to nearest RT provider (reference: nearest RT provider in patient's same zip code)				
RT distance Q1			0.97	0.99
RT distance Q2			1.02	1.04
RT distance Q3			0.90	0.92
RT distance Q4			1.01	1.03
Surgical facility ownership (reference: non-profit)				
Private/for-profit			1.36 **	1.35 **
Governmental			0.88 *	0.89 *
Teaching surgical facility			0.96	0.96
On-site RT at surgical facility			1.34 **	1.35 **
Fewer beds (< median)			1.08 *	1.08 *
NCI Comp. Cancer Center			0.57 **	0.57 **
ACoSOG affiliated			1.04	1.04
Selected patient clinical and sociodemographic variables				
NCI combined index co-morbidity score (reference: score of 0/no comorbidity)				
0.01–1		0.84 **	0.84 **	0.84 **
1.01–2		0.72 **	0.71 **	0.71 **
> 2.0		0.62 **	0.61 **	0.61 **
Stage at diagnosis (reference: stage 1)				

Independent variables	ORs reported with statistical significance			
	Naive model	**Adjusted model without health services variables**	**Adjusted model with health services variables**	**Fully adjusted model with health services variables and interactions**
2		0.76**	0.76**	0.76**
3		0.48**	0.47**	0.47**
Age (reference: 65–69 years)				
70–74		1.06	1.05	1.05
75–79		0.94	0.93	0.93
80–84		0.74**	0.73**	0.73**
85 and up		0.29**	0.29**	0.29**
Low income		0.71**	0.71**	0.71**
Married		1.25**	1.25**	1.25**
Observations	19,529	19,529	19,529	19,529

ACoSOG American College of Surgeons Oncology Group, *BCS* breast conserving surgery, *Comp* Comprehensive, *NCI* National Cancer Institute, *Q1–Q4* quartiles, *RT* radiation therapy

Robust standard errors used. Adjusted models also controlled for hormone receptor status, nodal status, grade, rural/urban residence, and zip code-level demographic and socio-economic variables

The bold values highlight the coefficients and significance of the main effect of race/ethnicity and how these change over time.

* Significant at 5%

** Significant at 1%

Table 4

Comparative logistic regression models for receipt of RT within 6-months post-diagnosis, by race/ethnicity, among women who received BCS (excluding those who died or received chemotherapy or mastectomy during that 6-month interval)

Independent variables	ORs reported with statistical significance			
	Naive model	**Adjusted model without health services variables**	**Adjusted model with health services variables**	**Fully adjusted model with health services variables and interactions**
Race/ethnicity (reference: non-Hispanic white)				
Non-Hispanic black	**0.58** **	**0.66** **	**0.66** **	**0.70**
Hispanic	**1.08**	**1.19**	**1.19**	**2.61** *
Structural/organizational health services variables				
Interactions (reference: white, nearest RT provider in patient's same zip code)				
Black × RT distance Q1				0.81
Black × RT distance Q2				0.43
Black × RT distance Q3				0.85
Black × RT distance Q4				0.69
Hispanic × RT distance Q1				1.01
Hispanic × RT distance Q2				0.34 *
Hispanic × RT distance Q3				1.69
Hispanic × RT distance Q4				0.26 **
Distance to nearest RT provider (reference: nearest RT provider in patient's same zip code)				
RT distance Q1			0.86	0.89
RT distance Q2			0.86	0.87
RT distance Q3			0.79 **	0.81 **
RT distance Q4			0.77 **	0.79 **
Surgical facility ownership (reference: non-profit)				
Private/for-profit			1.21	1.20
Governmental			0.83 **	0.84 **
Teaching surgical facility			1.05	1.05
On-site RT at surgical facility			1.34 **	1.35 **
Fewer beds (< median)			1.18 **	1.18 **
NCI Comp. Cancer Center			0.95	0.96
ACoSOG affiliated			1.10	1.10
Selected patient clinical and sociodemographic variables				
NCI combined index co-morbidity score (reference: score of 0/no comorbidity)				
0.01–1		0.88 *	0.88 *	0.88 *
1.01–2		0.61 **	0.61 **	0.61 **
> 2.0		0.49 **	0.48 **	0.48 **
Stage at diagnosis (reference: stage 1)				

Independent variables	ORs reported with statistical significance			
	Naive model	**Adjusted model without health services variables**	**Adjusted model with health services variables**	**Fully adjusted model with health services variables and interactions**
2		0.68 **	0.68 **	0.68 **
3		0.43 **	0.43 **	0.43 **
Age (reference: 65–69 years)				
70–74		0.85	0.85	0.85
75–79		0.57 **	0.57 **	0.57 **
80–84		0.31 **	0.31 **	0.31 **
85 and up		0.10 **	0.10 **	0.10 **
Low income		0.60 **	0.60 **	0.60 **
Married		1.27 **	1.27 **	1.28 **
Observations	18,017	18,017	18,017	18,017

Robust standard errors used. Adjusted models also controlled for hormone receptor status, nodal status, grade, rural/urban residence, and zip code-level demographic and socio-economic variables

ACoSOG American College of Surgeons Oncology Group, *BCS* breast conserving surgery, *Comp* comprehensive, *NCI* National Cancer Institute, *Q1–Q4* quartiles, *RT* radiation therapy

The bold values highlight the coefficients and significance of the main effect of race/ethnicity and how these change over time.

* Significant at 5%

** Significant at 1%

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Table 5

Comparative logistic regression models for receipt of RT within 12-months post-diagnosis, by race/ethnicity, among women who received BCS (excluding those who died or received chemotherapy or mastectomy during that 12-month interval)

Independent variables	ORs reported with statistical significance			
	Naive model	**Adjusted model without health services variables**	**Adjusted model with health services variables**	**Fully adjusted model with health services variables and interactions**
Race/ethnicity (reference: non-Hispanic white)				
Non-Hispanic black	**0.62** **	**0.71** **	**0.71** **	**0.78**
Hispanic	**1.10**	**1.21**	**1.22**	**2.38** *
Structural/organizational health services variables				
Interactions (reference: white, nearest RT provider in patient's same zip code)				
Black × RT distance Q1				0.86
Black × RT distance Q2				0.52
Black × RT distance Q3				0.73
Black × RT distance Q4				0.86
Hispanic × RT distance Q1				0.93
Hispanic × RT distance Q2				0.32 *
Hispanic × RT distance Q3				1.42
Hispanic × RT distance Q4				0.32 *
Distance to nearest RT provider (reference: nearest RT provider in patient's same zip code)				
RT distance Q1			0.86	0.87
RT distance Q2			0.84	0.86
RT distance Q3			0.77 **	0.79 **
RT distance Q4			0.77 **	0.79 **
Surgical facility ownership (reference: non-profit)				
Private/for-profit			1.18	1.17
Governmental			0.85 *	0.86 *
Teaching surgical facility			1.05	1.05
On-site RT at surgical facility			1.33 **	1.34 **
Fewer beds (< median)			1.16 **	1.16 **
NCI Comp. Cancer Center			0.94	0.94
ACoSOG affiliated			1.12	1.12
Selected patient clinical and sociodemographic variables				
NCI combined index co-morbidity score (reference: score of 0/no comorbidity)				
0.01–1		0.87 *	0.87 *	0.87 **
1.01–2		0.63 **	0.63 **	0.63 **
> 2.0		0.43 **	0.43 **	0.43 **
Stage at diagnosis (reference: stage 1)				

Independent variables	ORs reported with statistical significance			
	Naive model	**Adjusted model without health services variables**	**Adjusted model with health services variables**	**Fully adjusted model with health services variables and interactions**
2		0.69 **	0.69 **	0.69 **
3		0.48 **	0.48 **	0.48 **
Age (reference: 65–69 years)				
70–74		0.89	0.88	0.89
75–79		0.55 **	0.55 **	0.56 **
80–84		0.30 **	0.30 **	0.30 **
85 and up		0.10 **	0.10 **	0.10 **
Low income		0.58 **	0.59 **	0.59 **
Married		1.28 **	1.29 **	1.29 **
Observations	17,393	17,393	17,393	17,393

Robust standard errors used. Adjusted models also controlled for hormone receptor status, nodal status, grade, rural/urban residence, and zip code-level demographic and socio-economic variables

ACoSOG American College of Surgeons Oncology Group, *BCS* breast conserving surgery, *Comp* comprehensive, *NCI* National Cancer Institute, *Q1–Q4* quartiles, *RT* radiation therapy

The bold values highlight the coefficients and significance of the main effect of race/ethnicity and how these change over time.

* Significant at 5%

** Significant at 1%