Effects of Distance to Care and Rural or Urban Residence on Receipt of Radiation Therapy Among North Carolina Medicare Enrollees With Breast Cancer

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BACKGROUND Distance to oncology service providers and rurality may affect receipt of guideline-recommended radiation therapy (RT), but the extent to which these factors affect the care of Medicare-insured patients is unknown.

METHODS Using cancer registry data linked to Medicare claims from the Integrated Cancer Information and Surveillance System (ICISS), we identified all women aged 65 years or older who were diagnosed with stage I, II, or III breast cancer from 2003 through 2005, who had Medicare claims through 2006, and who were clinically eligible for RT. We geocoded the address of each RT service provider's practice location and calculated the travel distance from each patient's residential address to the nearest RT provider. We used ZIP codes to classify each patient's residence as rural or urban according to rural-urban commuting area codes. We used generalized estimating equations models with county-level clustering and interaction terms between distance categories and rural-urban status to estimate the effect of distance to care and rural-urban status on receipt of RT.

RESULTS In urban areas, increasing distance to the nearest RT provider was associated with a lower likelihood of receiving RT (odds ratio [OR] = 0.54; 95% confidence interval [CI], 0.30–0.97) for those living more than 20 miles from the nearest RT provider compared with those living less than 10 miles away. In rural areas, those living within 10–20 miles of the nearest RT provider were more likely to receive RT than those living less than 10 miles away (OR = 1.73; 95% CI, 1.08–2.76).

LIMITATIONS Results may not be generalizable to areas outside North Carolina or to non-Medicare populations.

CONCLUSIONS Coordinated outreach programs targeted differently to rural and urban patients may be necessary to improve the quality of oncology care.

Differences in the quality of breast cancer care, which can directly influence health outcomes, have been documented across different settings and subpopulations [1-5]. A variety of patient, provider, and health system factors can contribute to poor-quality cancer care [6-10]. An underappreciated factor that influences quality of care is access to oncology service providers [11, 12]. Cancer patients who must travel long distances to reach oncology care providers are potentially at high risk of going untreated or being undertreated [11, 13-15]. In addition, differential availability of resources such as transportation across rural and urban settings may contribute to differences in the quality of care patients receive [16, 17]. Treatments that require frequent visits to a provider, such as radiation therapy (RT), may be particularly sensitive to geographic barriers. The extent to which distance to care and rurality influence receipt of guideline-recommended RT by breast cancer patients in North Carolina is unknown.

Distance to care has been shown to affect receipt of appropriate cancer screening and treatment in a variety of settings [10, 11, 18-26]. However, studies of the relationship between distance to care and cancer care utilization have been inconsistent, possibly due to variability in how distance to care is measured. In addition, such variation may be greater in suburban and rural areas than in urban areas [27, 28]. To our knowledge, no published studies have evaluated the impact of distance to care and rurality on receipt of breast cancer treatment in North Carolina. Because North Carolina is a large, diverse state with a variety of rural and urban environments, it is important to understand how quality of care for breast cancer varies across these settings.

In light of these gaps and to understand barriers to care in North Carolina, we sought to examine geographic variables and receipt of care. Specifically, we assessed whether the distance to oncology service providers and rural or urban residence explained a portion of the variation in receipt of adjuvant RT among Medicare-insured breast cancer patients who had completed surgery.

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Methods

Data sources. For our analyses, we employed a novel data resource, the North Carolina Integrated Cancer Information and Surveillance System (ICISS). [Editor's note: For more information about ICISS, refer to the commentary by Meyer and colleagues on pages 265-269]. This statewide, population-based data set includes cancer registry data and multipayer insurance claims data; because of its richness and comprehensiveness, ICISS is uniquely suited to evaluate distance to care and quality of care. ICISS covers a wide variety of geographic subregions, with varying densities and distributions of populations and health care facilities, and it includes physician identifiers and geocoded patient and physician locations. The cancer registry data provide detailed clinical information about cancer diagnosis, stage, grade, and biomarker status, as well as demographic information about patients. The Medicare claims data include demographic information and details about any health care services or procedures for which an insurance claim was filed, along with corresponding diagnoses.

Cohort selection. We created a retrospective cohort that included women diagnosed with breast cancer between January 1, 2003, and December 31, 2005 whose records could be linked to Medicare insurance claims. Using the North Carolina Central Cancer Registry (NCCCR), we identified all women aged 65 years or older who were diagnosed with stage I, II, or III breast cancer from 2003 through 2005; we then linked these patient records to Medicare claims data to identify services and procedures received from 3 months before diagnosis through 1 year after diagnosis. To identify women who clearly met clinical guidelines for RT [29, 30], we limited our sample to women who had undergone breast-conserving surgery or who had undergone mastectomy and had tumors larger than 5 cm, using claims-based definitions from prior research [10, 31]. Although women with lymph-node–positive disease are also candidates for RT, we chose to focus specifically on indications for RT of the breast rather than RT of the axilla.

Using the registry, we obtained records for 7,653 women with breast cancer that was newly diagnosed from 2003 through 2005. We then excluded patients diagnosed at death (n = 7); patients without complete claims from 3 months before through 12 months after diagnosis (n = 1,987); patients with stage 0, stage IV, or unstaged disease (n = 1,608); patients who did not meet clinical criteria for RT (n = 516); and patients with end-stage renal disease (n = 1). Among the remaining women, we further limited our sample to women who had undergone breast-conserving surgery (n = 1,798) or women who had undergone mastectomy and had tumors larger than 5 cm (n = 140).

Measurement of RT (dependent variable). We used Medicare claims to determine whether RT was ever received within 1 year of diagnosis, as was done in prior studies [10, 32]. We used the procedure codes listed in Table 1 to identify surgeries and RT performed following a breast cancer diagnosis.

Measurement of distance to care (independent variable). To enable calculation of distance to RT providers, we identified all physicians in the claims database who provided RT to Medicare-insured breast cancer patients from 2003 through 2005. Using the physicians' unique physician identification numbers (assigned by Medicare), we obtained physician address information from the Registry of Medicare Physician Identification and Eligibility Records. We then used this information to build a master list of all physicians providing RT to breast cancer patients in North Carolina and the physicians' addresses.

Patient addresses were geocoded by NCCCR, following guidelines published by the North American Association of Central Cancer Registries [33]. In this study, the initial geocoding of physician addresses was performed by Mapping Analytics, a firm that provides custom mapping and analysis services. The remaining unmatched addresses (approximately 15%) were cleaned and geocoded using Esri ArcGIS 10.1 software [34], which increased the match rate to greater than 95%. Road network distances were then computed from every patient in the sample to every phy-

TABLE 1.
Codes Used to Identify Breast Cancer Treatments

Type of code	Codes used
Diagnosis code	ICD-9-CM diagnosis codes 174.0, 174.1, 174.2, 174.3, 174.4, 174.5, 174.6, 174.8, 174.9, 238.3, 239.3, V10.3
Code for aggressive mastectomy	ICD-9-CM procedure codes 85.41, 85.42, 85.43, 85.44, 85.45, 85.46, 85.47, 85.48
	CPT/HCPCS codes 19140–19180, 19182, 19200, 19220, 19240, 19260–19272, 19303–19307
Code for breast-conserving surgery	ICD-9-CM procedure codes 85.20, 85.21, 85.22, 85.23, 85.24, 85.25
	CPT/HCPCS codes 19110, 19120, 19125, 19126, 19160, 19162, 19301, 19302
Code for radiation therapy	ICD-9-CM procedure codes 92.21–92.29
	CPT/HCPCS codes 77260–77499, 77520, 77522, 77523, 77525, 77750–77799, 0073T, G0256, G0261
	Revenue center codes 0330, 0333, 0339
	Diagnosis-related group code 409
	ICD-9-CM diagnosis codes V58.0, V66.1, V67.1

Note. CPT, current procedural terminology; HCPCS, Healthcare Common Procedure Coding System; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

sician in the state who provided RT to Medicare enrollees with breast cancer. These distances were calculated using ArcGIS's Network Analyst extension and street data from Esri's StreetMap Premium for ArcGIS to identify road networks between the patient and the physician. *Distance to nearest provider* was defined as the shortest road-network path from the patient's address to that of the nearest RT provider.

We also computed Euclidean (straight-line) distances between providers and patients using the GEODIST function of SAS software [35]. We examined both the Euclidean and road-network measurements of distance to care and explored differences between them, but we opted to focus on road-network distances only, as they are known to be more accurate [28, 36]. We chose to measure the shortest distance rather than the shortest travel time because distance (based on the length of the road features in the GIS data set) is a more reliable measure than time calculations (based on imprecise speed attributes assigned to road segments). We examined multiple specifications of distance in sensitivity analyses, including distance measured continuously and in 5-mile and 10-mile categorical increments. We opted to use 10-mile categorical increments (less than 10 miles; 10–20 miles; and greater than 20 miles) in the primary analysis because they provided improved model fit statistics and larger cell sizes with less granular categorization (resulting in better model stability).

Classification of residence as rural or urban (independent variable). We used ZIP code information to determine whether each patient's address was rural or urban according to the rural-urban commuting area (RUCA) codes crosswalk, version 2.0, created by the Rural Health Research Center [37]. We created a binary measure for rural-urban status following guidance from the Rural Health Research Center. The RUCA rural-urban classification system combines information about population and commuting relationships, and researchers have used this system to compare urban and rural differences in more detail than is possible using the county-level definition [38-41]. We interacted our categorical distance measures with rural-urban status to test whether the effect of distance to RT providers is different in rural areas than in urban areas.

Covariates. As was done in previously published research [10, 31, 32], we adjusted models to account for patient sociodemographic characteristics that have previously been shown to influence receipt of RT, including age (65–69 years; 70–74 years; 75–79 years; 80 years or older), race (nonwhite; white), marital status (married; not married), and state buy-in (whether the state pays the individual's Medicare premiums, which serves as a binary proxy for low-income status) [42]. We also adjusted for important disease characteristics, including American Joint Commission on Cancer stage (stage I; stage II; stage III), hormone receptor status at diagnosis, which is based on whether the tumor has estrogen and/or progesterone receptors (negative; positive; or unknown), any prior cancer, and year of diagnosis. We recoded variables with missing data in order to retain as many observations as possible. For example, there were many women for whom the hormone receptor status of their tumor was unknown; therefore we created a separate category, "unknown."

Using methods consistent with those described in previously published research [10, 31, 43], we adjusted for comorbidities identified from Medicare claims using the National Cancer Institute Combined Index, with some modification to allow us to capture comorbid conditions co-occurring during the cancer treatment period [44]. Specifically, comorbidity was measured according to the Charlson Index from 3 months prior to diagnosis through 12 months after diagnosis, and breast-cancer–specific weights were calculated for each condition [44].

Lastly, studies have shown that county-level characteristics may affect receipt of health care services [45-47]. Therefore, as has been done in other studies [48, 49], we controlled for the following sociodemographic characteristics at the county level: percentage of the population that is nonwhite, population density, and median household income, all of which were obtained from the Area Resource File published in 2000 by the Health Resources and Services Administration [50].

Analyses. We used descriptive statistics to examine distributions in the data, performed bivariate analyses employing chi-squared tests for categorical variables, and performed *t* tests for continuous variables. We then used a generalized estimating equations (GEE) model with logit link function, exchangeable working correlation, and county-level clustering to examine the effect of geospatial measures on receipt of RT after breast-conserving surgery, controlling for other known confounders. The GEE model obtains population-based estimates by accounting for variances in correlated data (ie, people living in the same county share county-level characteristics) [51]. Individuals residing in the same county are no longer considered independent observations; therefore a GEE model is appropriate for patients living in the same geographic area, who are expected to be more related (correlated) to one another than to those living in different areas. Without such adjustment, the variance estimates tend to produce biased and smaller standard errors, which can lead to biased conclusions.

To determine whether distance to care had different effects in urban areas than in rural areas, we included interaction terms between the rural-urban indicator variable and categorical distance variables, and we conducted a Wald test to determine the significance of the overall interaction effect. We calculated odds ratios (ORs) for our overall model and stratified by rural-urban residence. All analyses were conducted using SAS version 9.3 software [35].

This study was approved by the institutional review board of the University of North Carolina at Chapel Hill.

Results

The final analysis sample included 1,938 patients living in 98 different counties in North Carolina, with between 1 and 131 women in each county. Overall, 65% of the women in the study sample received guideline-recommended RT. Table 2 presents the sample characteristics and the results of bivariate analyses, by receipt of RT. More than 50% of the women in our sample lived within 10 miles of a physician who provided RT. There were statistically significant differences in receipt of RT among the 3 distance-to-care categories and between rural residents and urban residents.

TABLE 2.
Sample Characteristics and Bivariate Results by Radiation Therapy (RT) Status

Variable	Total sample (N = 1,938)	Received RT (n = 1,253)	Did not receive RT (n = 685)	*P*-value
Age group				
65–69 years	534 (28%)	415 (33%)	119 (17%)	<.001
70–74 years	510 (26%)	358 (29%)	152 (22%)	
75–79 years	480 (25%)	291 (23%)	189 (28%)	
80 years or older	414 (21%)	189 (15%)	225 (33%)	
Race				
White	1,655 (85%)	1,082 (86%)	573 (84%)	.10
Nonwhite	283 (15%)	171 (14%)	112 (16%)	
Marital status				
Married	807 (42%)	588 (47%)	219 (32%)	<.001
Not married	1,131 (58%)	665 (53%)	466 (68%)	
State Medicare buy-in[a]				
Buy-in	295 (15%)	155 (12%)	140 (20%)	<.001
No buy-in	1,643 (85%)	1,098 (88%)	545 (80%)	
AJCC stage at diagnosis				
Stage I	1,181 (61%)	740 (59%)	441 (64%)	<.001
Stage II	570 (29%)	363 (29%)	207 (30%)	
Stage III	187 (10%)	150 (12%)	37 (5%)	
Hormone receptor status of tumor[b]				
ER/PR negative	144 (7%)	92 (7%)	52 (8%)	.20
ER/PR positive	746 (38%)	465 (37%)	281 (41%)	
Unknown	1,048 (54%)	696 (56%)	352 (51%)	
Year of diagnosis				
2003	529 (27%)	379 (30%)	150 (22%)	<.001
2004	803 (41%)	520 (42%)	283 (41%)	
2005	606 (31%)	354 (28%)	252 (37%)	
Comorbidity index score[c]	0.358	0.317	0.433	<.001
Prior cancer				
Yes	325 (17%)	197 (16%)	128 (19%)	.10
No	1,613 (83%)	1,056 (84%)	557 (81%)	
Urban or rural residence, at zip code level				
Urban	1,276 (66%)	857 (68%)	419 (61%)	<.01
Rural	662 (34%)	396 (32%)	266 (39%)	
Road network distance to nearest provider				
Less than 10 miles	1,075 (55%)	711 (57%)	364 (53%)	<.01
10–20 miles	425 (22%)	290 (23%)	135 (20%)	
Greater than 20 miles	438 (23%)	252 (20%)	186 (27%)	
County-level predictors				
Mean % of population nonwhite	27.14	26.88	27.61	.28
Mean population density per square mile	364	379	336.4	<.01
Median household income	$39,907	$40,241	$39,297	<.01

Note. AJCC, American Joint Committee on Cancer; ER, estrogen receptor; PR, progesterone receptor.
[a]Medicare buy-in means that the state of North Carolina was paying the patient's Medicare premiums; this was used as a proxy for low-income status.
[b]Hormone receptor status was classified as positive if the patient's tumor had any estrogen receptors or progesterone receptors; it was classified as negative if the tumor had no estrogen receptors or progesterone receptors.
[c]The higher the comorbidity index score, the greater the number of comorbid conditions.

In general, women who received RT were younger, more likely to be married, and more likely to be higher-income compared with women who did not receive RT; women who received RT were also generally diagnosed in earlier study years, had cancer that was more advanced, and had fewer comorbid conditions. Women who lived in counties with a higher population density and/or higher median household income were also more likely to receive RT.

The results of multivariable analyses are presented in Table 3. With respect to distance to RT providers and rural-urban status, the results indicate significant interaction effects between these 2 variables (Wald statistic = 6.97; $P<.05$). In the subsample of urban patients, increasing distance to the nearest RT provider was significantly associated with lower odds of receiving RT (OR = 0.54; 95% confidence interval [CI], 0.30–0.97) for those living at least 20 miles from the nearest provider, compared with those living less than 10 miles from the nearest provider (see Table 4). In the subsample of breast cancer patients residing in rural areas, increasing distance to the nearest RT provider was significantly associated with higher odds of receiving RT (OR = 1.73; 95% CI, 1.08–2.76) for those living within 10–20 miles of the nearest RT provider compared with those living less than 10 miles from the nearest RT provider. For those living more than 20 miles from the nearest provider, distance did not significantly affect receipt of RT, compared with those living less than 10 miles from the nearest provider.

After controlling for all other factors, the odds of receiving RT were significantly higher for women who were married (OR = 1.40; 95% CI, 1.12–1.74) and for those diagnosed with stage III disease compared with stage I disease (OR = 2.93; 95% CI, 1.94–4.42). The odds of receiving RT were significantly lower for several groups of women: those older than 80 years compared with those aged 65–69 years (OR = 0.27; 95% CI, 0.21–0.35); those with lower incomes (OR = 0.66; 95% CI, 0.49–0.89); those diagnosed in 2004 compared with those diagnosed in 2003 (OR = 0.72; 95% CI, 0.56–0.92) or those diagnosed in 2005 compared with those diagnosed in 2003 (OR = 0.54; 95% CI, 0.35–0.82); and those with higher comorbidity scores (OR = 0.82; 95% CI, 0.70–0.98).

To further evaluate the robustness of the differential distance effect between urban and rural residence, we conducted a stratified analysis separating urban and rural samples while keeping all of the covariates in both models (results not shown). Statistically significant effects persisted in rural areas for the distance category of 10–20 miles, compared with less than 10 miles (OR = 1.76; 95% CI, 1.07–2.87). For urban areas, the significant finding for the distance category of greater than 20 miles, compared with less than 10 miles, becomes marginally significant (OR = 0.57; 95% CI, 0.32–1.02; Table 4). In addition, we grouped the distance categories in 5-mile increments and still found a significant distance effect in rural areas for the category of 15–20 miles, compared with less than 5 miles (OR = 2.14;

TABLE 3.
Multivariable Generalized Estimating Equations Model Results for Receipt of Radiation Therapy (RT), with County-Level Clustering (N = 1,938)

Variable	Estimated odds ratio (95% CI)	*P*-value
Age group		
65–69 years (reference)	1.00	
70–74 years	0.70 (0.52–0.94)	.02
75–79 years	0.47 (0.38–0.59)	<.0001
80 years or older	0.27 (0.21–0.35)	<.0001
Race		
Nonwhite (reference)	1.00	
White	1.04 (0.79–1.38)	.762
Marital status		
Not married (reference)	1.00	
Married	1.40 (1.12–1.74)	.003
State Medicare buy-in[a]		
No buy-in (reference)	1.00	
Buy-in	0.66 (0.49–0.89)	.006
AJCC stage at diagnosis		
Stage I (reference)	1.00	
Stage II	1.07 (0.89–1.30)	.452
Stage III	2.93 (1.94–4.42)	<.0001
Hormone receptor status of tumor[b]		
ER/PR negative (reference)	1.00	
ER/PR positive	1.16 (0.68–1.96)	.585
Unknown	0.95 (0.55–1.63)	.845
Year of diagnosis		
2003 (reference)	1.00	
2004	0.72 (0.56–0.92)	.009
2005	0.54 (0.35–0.82)	.004
Comorbidity index score	0.82 (0.70–0.98)	.03
Prior cancer		
No (reference)	1.00	
Yes	0.96 (0.74–1.26)	.790
Urban or rural residence at ZIP code level		
Rural (reference)	1.00	
Urban	1.91 (1.23–2.96)	.004
Road network distance to nearest RT provider		
Less than 10 miles (reference)	1.00	
10–20 miles	1.73 (1.08–2.76)	.02
Greater than 20 miles	1.09 (0.73–1.63)	.662
Urban or rural residence and road network distance interaction		
Rural × less than 10 miles (reference)	1.00	
Urban × 10–20 miles	0.50 (0.27–0.94)	.03
Urban × greater than 20 miles	0.50 (0.24–1.02)	.058
County-level predictors		
Mean % of population nonwhite	0.99 (0.98–1.01)	.313
Population density	0.99 (0.98–1.01)	.309
Median household income	1.00 (1.00–1.00)	.439

Note. AJCC, American Joint Committee on Cancer; CI, confidence interval; ER, estrogen receptor; PR, progesterone receptor.
[a]Medicare buy-in means that the state of North Carolina was paying the patient's Medicare premiums; this was used as a proxy for low-income status.
[b]Hormone receptor status was classified as positive if the patient's tumor had any estrogen receptors or progesterone receptors; it was classified as negative if the tumor had no estrogen receptors or progesterone receptors.

95% CI, 1.05–4.34). In urban areas, we found a marginally significant effect for the distance category of greater than 20 miles, compared with less than 5 miles (OR = 0.55; 95% CI, 0.3–1.01).

Discussion

We examined receipt of RT as a metric that reflects the quality of breast cancer care and patients' access to oncology service providers. We found that distance to care and rural-urban status were significantly associated with receipt of RT by breast cancer patients for whom RT was clinically indicated. Within urban areas, increasing distance to the nearest RT provider was generally associated with lower likelihood of receiving RT; in rural areas, living within 10–20 miles of the nearest RT provider was associated with greater odds of receiving RT, compared with living less than 10 miles from the nearest RT provider.

These findings may be explained in several ways. First, urban residents may be more likely to rely on public transportation than on personal transportation to reach health providers, and the burden of accessing care via this mode of transportation (which operates on set schedules) is likely to be greater as distance to care increases. In an urban area, living more than 20 miles away from the nearest RT provider may mean commuting an hour or more (via either public or personal transportation), and this may be an insurmountable barrier for elderly women with cancer.

In contrast, rural residents may be more likely to rely on personal transportation to access health care services and may be more accustomed to traveling longer distances for health care, because they often travel long distances to access other types of goods and services. As a result, people in the most remote rural areas (and by extension, those furthest from RT providers) may be more willing or able to drive further to access health care and other types of goods and services, and they may combine visits to health care providers with other errands. This supposition is supported by the research of Gesler and colleagues [52], who found that more than 85% of rural health care visits involved transportation by private car. Arcury and colleagues [17] found that in rural North Carolina, access to transportation—having a driver's license or knowing someone who could provide transportation—was more important for health care utilization than distance to health care providers. In addition, residents of the most remote rural areas may be more willing to bypass the nearest RT provider in order to access oncology care at a larger, more centralized facility that is affiliated with a medical school or a cooperative group such as the Eastern Cooperative Oncology Group (ECOG), the National Surgical Adjuvant Breast and Bowel Project (NSABP), the North Central Cancer Treatment Group (NCCTG), or the Southwest Oncology Group (SWOG) [53, 54]. Our distance-to-care measure assessed distance to the nearest provider; as a next step in future analyses, it would be important to explore whether women living in the most remote areas are bypassing closer RT providers to obtain care at a larger health care facility and, if so, how far they are traveling to do so.

The interaction effects between distance to care and rural-urban residence suggest that rural and urban settings in North Carolina differ in terms of how distance to a health care provider affects access to care. These findings imply a need to consider these settings differently when planning interventions. Specifically, cancer patients living in urban environments may benefit from dedicated buses that transport multiple patients to and from RT (and chemotherapy) appointments, organized carpools, or public transportation vouchers. Experience suggests that such programs are fragmented, often poorly organized, and unequally distributed across providers and patients. In contrast, cancer patients living in rural areas, who are accustomed to driving themselves to RT and other health care appointments, may benefit from parking vouchers and reimbursement for gasoline. Because it may not be pragmatic or logistically feasible to organize group transportation for patients living in disparate and remote rural areas, and because our research suggests that factors beyond distance to care may present greater barriers for rural women, efforts should focus on targeting assistance to the most vulnerable rural patients (eg, women who are poor, older, and/or socially isolated). Community-based nonprofit organizations, cancer support networks, insurers/payers, and health care facilities may be able to pool resources to support such initiatives. Both large academic cancer centers and smaller community-based RT practices can play major roles in helping to coordinate and facilitate such options for patients in North Carolina.

Additional nonclinical factors—such as older age, being unmarried, and low-income status—were significantly associated with lack of RT, a finding that is consistent with the results of prior studies [2, 10, 32, 55]. Patients in these categories are likely to be more vulnerable, and they may require more intensive outreach, support, and resources to help ensure they receive guideline-recommended RT. Among women who lived near an RT provider yet did not receive RT, unmeasured factors—such as social isolation, lack of transportation, and frailty—may have prevented them from accessing RT despite the geographic nearness of providers [16].

Secondary, administrative, and linked data analyses have several inherent limitations. First, registry-linked claims data do not reveal anything about patient-provider communication in decision making; therefore, it is impossible to discern whether RT was foregone or delayed for a clinically valid reason. Second, because these data are specific to North Carolina, our findings may not be generalizable to other states and settings. In particular, because our analysis required continuous enrollment in fee-for-service Medicare, our results may not be applicable to patients enrolled in health maintenance organizations or other insurance plans or to patients with more transient health insurance coverage. Third, geospatial methods and measurement of dis-

TABLE 4.
Effects of Distance to Nearest Radiation Therapy (RT) Care Provider on Receipt of RT, by Rural-Urban Status

Distance to care (reference group, less than 10 miles)	Urban dwellers (n = 1,276) Odds ratio (95% CI)	*P*-value	Rural dwellers (n = 662) Odds ratio (95% CI)	*P*-value
10–20 miles	0.87 (0.61–1.24)	.444	1.73 (1.08–2.76)	.022
Greater than 20 miles	0.54 (0.30–0.97)	.040	1.09 (0.73–1.63)	.662

Note. CI, confidence interval.
These odds ratios and confidence intervals were computed using the SAS estimate statement in the generalized estimating equations multivariable model presented in Table 3 (including the exact same covariates). To obtain the odds ratio of the interaction between distance to care of 10–20 miles (versus <10 miles) within urban areas, in the estimate statement we set the parameters to 1 for both 10–20 miles and the interaction term of "10–20 miles * urban area."

tance to care are evolving sciences, and our approach may not be perfect. With more granular location data about patients and providers, analyses might reveal different or more complex relationships between distance to care and receipt of RT [56].

In summary, this study sought to understand geographic predictors of underuse of guideline-recommended RT among elderly breast cancer patients in North Carolina. Using a novel, population-based cancer data system—the Integrated Cancer Information and Surveillance System (ICISS), which is supported by the state of North Carolina through the University Cancer Research Fund—we found that distance to RT providers and rural-urban residence were important correlates of receipt of RT, controlling for all other factors, and that observed effects of distance to care were different in rural versus urban areas. These findings suggest that the subpopulations of breast cancer patients who are most vulnerable to underuse of life-prolonging therapies may need to be targeted for intervention and supported in creative ways to ensure their access to oncology care services. NCMJ

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