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ORIGINAL REPORT

Impact of Patient Distance to Radiation Therapy on Mastectomy Use in Early-Stage Breast Cancer Patients

Anneke T. Schroen, David R. Brenin, Maria D. Kelly, William A. Knaus, and Craig L. Slingluff Jr

From the Departments of Surgery, Health Evaluation Sciences, and Radiation Oncology, University of Virginia, Charlottesville, VA.

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Address reprint requests to Anneke T. Schroen, MD, MPH, University of Virginia, Department of Surgery, PO Box 800709, Charlottesville, VA 22908-0709; e-mail: ats2x@virginia.edu.

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ABSTRACT

Purpose
Treatment access underlies quality cancer care. We hypothesize that mastectomy rates in a rural state are independently influenced by distance to radiation therapy (XRT) and by changing XRT access through opening new facilities.

Patients and Methods
Early-stage breast cancer patients diagnosed from 1996 to 2000 were identified in the Virginia state registry. Distance from patient zip code to nearest XRT facility was calculated with geographical software. Distance to XRT facility (≤ 10, > 10 to 25, > 25 to 50, and > 50 miles), American Joint Committee on Cancer tumor stage, age, race, and diagnosis year were evaluated for influencing mastectomy rate. Mastectomy use within 15 miles of five new facilities was assessed before and after opening.

Results
Among 20,094 patients, 43% underwent mastectomy, 53% underwent lumpectomy, and therapy of 4% of patients is unknown. Twenty-nine percent of patients lived more than 10 miles from XRT facility. Mastectomy increased with distance to XRT facility (43% at ≤ 10 miles, 47% at > 10 to 25 miles, 53% at > 25 to 50 miles, and 58% at > 50 miles; $P < .001$). Among 11,597 patients with T1 (< 2 cm) tumors, mastectomy also varied by distance (31% at ≤ 10 miles, 36% at > 10 to 25 miles, 41% at > 25 to 50 miles, and 49% at > 50 miles; $P < .001$). In multivariate analysis, mastectomy use was independently influenced by XRT distance after adjusting for age, race, T stage, and diagnosis year. Over the study period, mastectomy rates declined from 48% to 43% across Virginia, and there were similar declines in a 15-mile area around four new radiation facilities in urban settings. However, mastectomies decreased from 61% to 45% around a new XRT facility in a rural setting.

Conclusion
Distance to XRT facility significantly impacts mastectomy use. Opportunities for increasing breast-conservation rates through improved XRT access exist.

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INTRODUCTION

Access to appropriate and current cancer treatment resources is a fundamental condition for achieving universal, high-quality cancer care in the United States. The National Institutes of Health Consensus Conference statement of 1990 established breast conservation as a standard of quality care by concluding that "breast conservation treatment is an appropriate method of primary therapy for the majority of women with stage I and II breast cancer."[1] Breast-conserving therapy (BCT) entails surgical removal of the primary tumor with adequate margins, evaluation of the axillary nodes, and local breast irradiation. The use of BCT serves as an important measure of variation in treatment patterns for a population. Although clinician and patient preferences and socioeconomic factors have important roles in treatment patterns, another important and potentially mutable

factor in breast cancer treatment patterns is access to the radiation therapy (XRT) services essential to BCT.

Studies to date have been inconsistent in evaluating whether inconvenient geographic access to XRT serves as a deterrent to BCT.[2-7] Some studies demonstrated an association between lumpectomy rates and geographic proximity to XRT.[3,6,7] Other studies found an association between distance to XRT and adherence to recommended post-lumpectomy radiation but not with the lumpectomy rate itself.[2,4] A study evaluating patients in the Surveillance, Epidemiology, and End Results (SEER) program found that BCT decreased when patients lived in zip codes 15 or more miles from the nearest XRT facility. Within the SEER population, which is more urban than the overall US population, only 11% of women lived greater than 15 miles from a XRT facility.[6] It is anticipated that limited access to XRT would have a greater impact for the general US population. Furthermore, given that more than 200,000 women will be diagnosed with breast cancer annually, evaluating a modifiable factor, such as XRT accessibility, could influence treatment for thousands of patients each year, even if the proportion of patients affected is small.

Although increases in BCT have been noted during the 1980s and 1990s throughout the United States, lower rates of BCT have repeatedly been documented in states of the South Central or South Atlantic United States.[8,9] The basis for this geographic variation is not clear, but the significant variations seen in treatment patterns for breast cancer may suggest that factors related to providers or institutions heavily influence surgical decision making and possibly surpass patient choice in determining surgical treatment.[10] Variation in surgical breast cancer treatment stemming from patient choice is not an issue of appropriateness of care, provided that each woman is given fair and accurate treatment option information from which to make a choice and that XRT is logistically a feasible option. Practice variation resulting from inadequate access to care merits careful research on a regional level so that the results can target improvements in medical practice and health resource allocation.

This study comprehensively evaluates the impact of distance to XRT on surgical breast cancer treatment in Virginia, a southern state previously identified as having below-average BCT rates.[8] Virginia is an excellent state to study because of extreme regional differences in socioeconomic conditions and health care access. The state's population ranges from largely underserved rural areas in southwest Virginia, including Appalachian communities, to highly urbanized populations of the Tidewater area and the northern Virginia suburbs of Washington, DC. Clarifying the relationship of distance to XRT and treatment practices is also timely because the introduction of new technologies (eg, accelerated partial breast irradiation and accelerated hypofractionated XRT) may reshape certain barriers by significantly reducing the amount of time required to undergo XRT. This study was designed to determine whether greater distance to XRT is associated with higher mastectomy rates across a diverse population and to assess the impact of changing distance to XRT on surgical treatment patterns.

PATIENTS AND METHODS

Patient Identification and Characteristics

The study design was a cross-sectional analysis of all early-stage invasive breast cancer cases collected by the Virginia Cancer Registry (VCR) over a 5-year period. Virginia law requires cancer case reporting within 6 months of diagnosis. Mandatory case reporting went into effect in 1990 in Virginia. Cases are documented by patient residence, even if medical care is sought outside the state. The VCR estimates a 90% average complete case ascertainment rate in 1996 to 2000. All patients residing in Virginia who were diagnosed with local or regional breast cancer, as defined by the SEER program extent of disease (EOD) criteria, between January 1, 1996, and December 31, 2000, and whose cases were reported to the VCR by June 2003 were identified. Exclusion criteria included male breast cancers, carcinoma-in-situ, metastatic or recurrent breast cancer, and histology not consistent with adenocarcinoma. Patients without a zip code adequate for geographic mapping were also excluded. For the majority of patients, information pertaining to the American Joint Committee on Cancer staging criteria was available, but this information was not as complete as staging by SEER EOD criteria; therefore, EOD criteria were used to select eligible patients. Tumor size was categorized by American Joint Committee on Cancer definitions as T1 ($\leq$ 2 cm), T2 ($>$ 2 to 5 cm), and T3 ($>$ 5 cm). Tumor size measurements were available for 91% of eligible patients included in this study.

In addition to staging information, patient age at diagnosis and race were obtained from the VCR data for each patient. Race was coded as white, black, or other (including American Indian, Asian, and unknown). Primary surgical therapy was categorized as mastectomy, breast-conserving surgery (ie, lumpectomy, quadrantectomy, and segmental mastectomy), or unknown. In cases where both a breast-conserving procedure and a complete mastectomy were listed in the VCR data, mastectomy was considered the definitive surgical treatment and was coded as the surgical procedure for analysis. The VCR does not collect information regarding personal or family cancer history.

Distance to XRT Facilities

Thirty-seven XRT facilities were identified in Virginia through the cancer registry and the American Hospital Association Annual Survey of Hospitals 2002.[11] These facilities were confirmed by telephone call to be delivering breast XRT in 1996 to 2000. Facilities that opened during the study period were included for analysis in patients diagnosed the year after the opening of the XRT center. Two facilities opened during 1996 and were considered in evaluation of treatment patterns for patients diagnosed in 1997 or later; two facilities opened during 1997 and were included for patients diagnosed in 1998 or later; and one facility opened during 1998 and was included for patients diagnosed in 1999 or later. The distance from the centroid of each zip code in Virginia to the nearest XRT facility was calculated with the point distance tool in ArcGIS 8.0 (Environmental Systems Research Institute,

Redlands, CA), which is geographic software that allows calculation of straight-line distance. In calculating these distances, the XRT facilities available each year were considered, as summarized earlier. These date-specific distance calculations were then linked by zip code to each patient. Distances in miles were categorized as ≤ 10, more than 10 to 25, more than 25 to 50, and more than 50 miles.

Impact of Changing XRT Distance

Five new XRT facilities opened during the study period, creating an opportunity to study the impact of changing distance to XRT on surgical treatment patterns. Two facilities opened in Northern Virginia (facilities A and B), two opened in Eastern Virginia (facilities C and D), and one opened in Southwest Virginia (facility E). Facilities A through D are located in urban areas, whereas facility E is situated in a rural part of the state. The impact of changing XRT access is presented descriptively before and after opening the new XRT facility in the following two manners: by the proportion of breast cancer patients within a 50-mile radius around each of the five new XRT facilities who now live within 15 miles of an XRT facility and by the proportion of patients within 15 miles of a new XRT site receiving mastectomy. These data are presented by a 15-mile distance from an XRT site because this distance marked a significant difference in breast-conservation rates within the SEER population reported in a prior study. This study also used straight-line distance measurements, which served as a good comparison.[6] Because of the limited number of new facilities, more complex statistical analysis was not undertaken.

Data Analysis

The use of mastectomy versus breast-conserving surgery was evaluated by patient age, race, tumor size, SEER EOD criteria, year of diagnosis, and distance to nearest XRT facility using Pearson χ^2 test for categoric variables and the Student's t test or analysis of variance for continuous variables. To determine the significance of associations identified on bivariate analysis, a logistic regression model was used to calculate an odds ratio for undergoing mastectomy rather than breast conservation. These odds ratios were adjusted for patient age, race, year of diagnosis, SEER EOD, tumor size, and distance to nearest XRT facility. Analytic tests were performed with Stata 7.0 software (STATA Corp, College Station, TX). This project was approved separately by the Institutional Review Boards of the Virginia Department of Health and of the University of Virginia School of Medicine.

RESULTS

Patient Characteristics

During the 5-year study period, 20,287 women with local or regional breast cancer were reported across the state to the VCR. Seventy patients (38 with phyllodes tumors and 32 with sarcomatous tumors) were excluded based on histology. An additional 123 patients were excluded because they lacked a zip code that was recognized as a distinct geographic location by ArcGIS 8.0. A total of 20,094 patients (99%) remained for analysis. Table 1 lists the patient, tumor, and geographic characteristics of the study patients. Distances from zip code centroid to nearest XRT facility ranged from 0.2 to 85.4 miles, with a median distance to nearest XRT facility of 4.6 miles. Twenty-two percent of this cohort lived 15 or more miles from an XRT facility.

Patient Characteristics in Relation to Distance to XRT Facility

Race, age, and tumor size varied with distance to nearest XRT facility (complete data not shown) and were, therefore, included in the multivariate model. White women and older women were more likely to live further away from an XRT facility. Tumors of 2 cm or less in size were diagnosed in 53% of women living greater than 50 miles from an XRT facility and in approximately 63% of women living within 50 miles of an XRT facility ($P = .003$). Smaller tumors were also more likely to be diagnosed in white women and in older women. Interaction effects between tumor size and distance to XRT facility, as well as interactions between patient age or race and distance to XRT facility, were tested and not found to be significant in multivariate analysis (complete data not shown).

Surgical Treatment Patterns

The associations of mastectomy rate with patient age, race, year of diagnosis, tumor size, EOD, and distance to nearest XRT facility are listed in Table 1. Women greater than 70 years of age were more likely to undergo mastectomy than women younger than 70 years of age (49% *v* 43%, respectively; $P < .001$). Mastectomy rates increased with increasing tumor size. Among women younger than 70 years, 30% with T1 and 55% with T2 tumors underwent a mastectomy. In contrast, among women aged 70 years or older, 38% with T1 and 64% with T2 tumors underwent a mastectomy (data not shown). Although white and black women were treated with a mastectomy in equal proportions (44% *v* 45%, respectively), women of other races or ethnicities were treated with a higher rate of mastectomy (59%; $P < .001$).

Distance to XRT Facility and Mastectomy Rate

Increasing mastectomy rates were associated with longer distances from zip code centroid to nearest XRT facility (Fig 1 and Table 1). Among patients with T1 tumors alone, this association between higher mastectomy rate and greater distance to XRT facility was particularly evident (Fig 2). In the subset of women with T1 tumors, the mastectomy rate increased from 31% for women living less than 10 miles from an XRT facility to 49% for women living more than 50 miles from an XRT facility ($P < .001$; Fig 2). Adjusted odds ratios for treatment with mastectomy rather than breast-conserving surgery are listed in Table 2. Tumor size was the most influential determinant of procedure type and was consistent with standard recommended therapy. Increasing distance to nearest XRT facility had a significant and independent association with mastectomy use, even comparing 10 to 25 miles with less than 10 miles (Table 2).

Table 1. General Characteristics of Women With Breast Cancer Diagnosed Between 1996 and 2000 in Virginia and Features Associated With Surgical Treatment by Mastectomy

Characteristic	Patients (N = 20,094) No.	%	% of Patients With Surgical Procedure of Mastectomy (n = 19,295)
Age, years			
Mean	60.1		
SD	14.2		
Range	17-102		
Tumorsize, cm			
Mean	2.2		
SD	1.9		
Age			
< 40 years	1,341	7	45
40-49 years	3,878	19	42
50-59 years	4,849	24	42
60-69 years	4,222	21	43
≥ 70 years	5,803	29	49*
Race			
White	16,546	82	44
Black	3,137	16	45
Other	411	2	59*
Year of diagnosis			
1996	3,603	18	50
1997	3,797	19	46
1998	4,119	20	44
1999	4,228	21	42
2000	4,347	22	42*
Extent of disease			
Localized	13,745	68	36
Regional	6,349	32	63*
Tumor size, No.	18,238		17,804
T1	11,597	64	33
T2	5,477	30	57
T3	1,164	6	82*
Distance to nearest XRT facility			
< 10 miles	14,318	71	43
10 to < 25 miles	3,482	18	47
25 to < 50 miles	2,036	10	53
≥ 50 miles	258	1	58*
Surgical procedure			
Mastectomy	8,577	43	
Breast-conserving surgery	10,718	53	
Unknown	799	4	

NOTE. N = 20,094, patients in data set; n = 18,238, patients with tumor size known; n = 17,804, patients with both tumor size and surgical procedure known.
Abbreviations: SD, standard deviation; XRT, radiation therapy.
*$P < .001$, surgical procedure of mastectomy *v* lumpectomy.

Impact of Changing XRT Access on Surgical Treatment Patterns

Essentially, no change in the proportion of patients living within 15 miles of a new XRT facility was seen in the area around the two facilities located in densely urban Northern Virginia. In contrast, a relative decrease in the proportion of patients within a 50-mile radius of the facilities in Eastern and Southwest Virginia now living greater than 15 miles from the nearest XRT facility was seen (Table 3). Mastectomy use before and after a new facility opened for patients living within a 15-mile radius of each new facility is also shown in Table 3. These changes were viewed in the context of gradually declining mastectomy rates in the state as a whole over the 5-year study period (Fig 3). Mastectomy use declined most markedly in the patient population living in zip codes 15 miles or less around rural facility E after the facility opened in 1997. Within 15 miles of facility E, mastectomy rates decreased from 61% to 45%, whereas mastectomy rates in the state overall decreased from 48% to 43%.

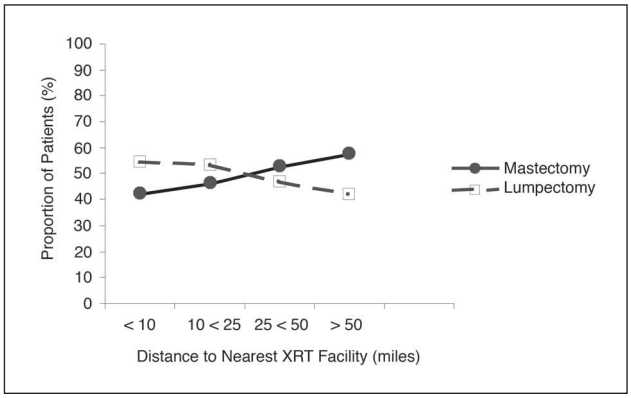

Fig 1. Relationship of surgical procedure and distance to nearest radiation therapy (XRT) facility.

DISCUSSION

Patient distance to the nearest XRT facility was independently associated with breast cancer surgical therapy within a state characterized by a diverse rural and urban population. The relationship between longer distance to the nearest XRT facility and higher mastectomy use was independent of tumor size, year of diagnosis, and patient age

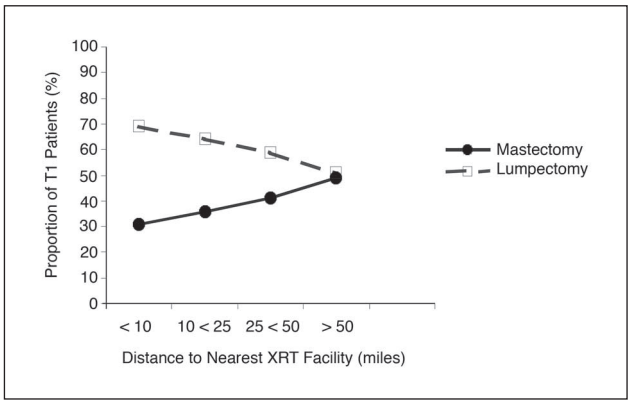

Fig 2. Relationship of surgical procedure and distance to nearest radiation therapy (XRT) facility for patients with T1 (≤ 2 cm) tumors.

Table 2. OR for Treatment With Mastectomy Rather Than Breast-Conserving Surgery Among Patients With Tumor Size and Surgical Procedure Known

Independent Variable	Mastectomy (n = 17,803) OR*	95% CI
Age		
< 40	1.0†	
40-49	1.04	0.90 to 1.20
50-59	1.10	0.96 to 1.27
60-69	1.31	1.13 to 1.51
≥ 70	1.78	1.55 to 2.05
Race		
White	1.0†	
Black	0.92	0.84 to 1.01
Other	1.93	1.53 to 2.42
Year of diagnosis		
1996	1.0†	
1997	0.87	0.79 to 0.97
1998	0.82	0.74 to 0.91
1999	0.78	0.70 to 0.86
2000	0.79	0.71 to 0.87
Extent of disease		
Localized	1.0†	
Regional	2.22	2.06 to 2.38
Tumor size		
T1	1.0†	
T2	2.38	2.22 to 2.56
T3	7.03	5.98 to 8.27
Distance to nearest XRT facility		
< 10 miles	1.0†	
10 to < 25 miles	1.18	1.08 to 1.28
25 to < 50 miles	1.45	1.30 to 1.62
> 50 miles	1.70	1.25 to 2.32

Abbreviations: OR, odds ratio; XRT, radiation therapy.
*Adjusted for patient age, race, year of diagnosis, tumor extent of disease and tumor size, and distance to nearest XRT facility for patient zip code.
†Reference category for dummy variables used in logistic regression model.

and race. This association with higher mastectomy use was noted with distances 10 miles or greater from the nearest XRT facility. The nearly linear relationship between distance to XRT and mastectomy use was evident for the entire patient population and also extended to analysis of patients with T1 tumors alone. From a standpoint of surgical technique, essentially every patient with a tumor 2 cm or smaller should be a candidate for breast-conserving surgery. Therefore, implications of an association between geographic access to XRT and surgical treatment patterns is particularly striking in this subgroup of patients with smaller tumors and represents a real opportunity for affecting treatment patterns.

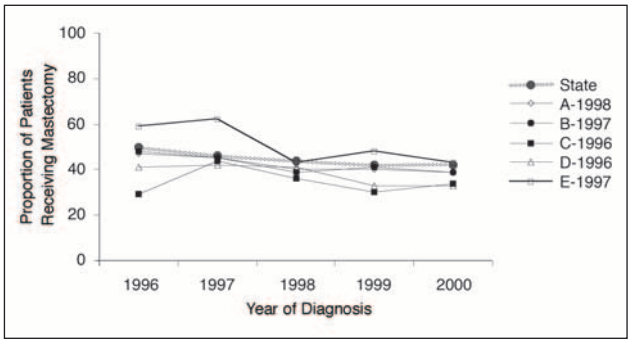

Fig 3. Percent of patients receiving mastectomy averaged per year for the state and for 15-mile radii around each new radiation therapy (XRT) facility. Years in legend indicate year new XRT facility opened.

Our study further suggests that a marked change in geographic access to XRT by opening new facilities may correlate with an increase in the proportion of patients undergoing breast conservation. Although new XRT facilities may have a significant impact on practice patterns, constructing new XRT facilities in rural or underserved areas may not be cost effective because of underutilization of the new facility. However, regional strategic planning studies should be conducted before reaching that conclusion. A less costly option includes providing patient housing assistance in proximity to XRT facilities. Housing assistance may well offer a financially sound alternative and serve as reasonable policy for states committed to improving access to care for rural communities.

New developments in accelerated partial breast irradiation[12-14] and accelerated hypofractionated irradiation of

Table 3. Change in Geographic Access to XRT As Measured by Proportion of Patients Within a 50-Mile Radius of a New XRT Facility Living Greater Than 15 Miles From Nearest XRT Facility and by Proportion of Patients in 15-Mile Radius of New-XRT Facility Receiving Mastectomy

New XRT Facility	Year Opened	Within 50-Mile Radius of New XRT Facility, the Proportion of Patients Living ≥ 15 Miles From Nearest XRT Facility (%)		Within 15-Mile Radius of New XRT Facility, the Proportion of Patients Receiving Mastectomy (%)	
		Before Opening	After Opening	Before Opening	After Opening
A	1998	7.9	7.7	43.9	39.7
B	1997	8.8	8.4	46.8	39.8
C	1996	11.3	6.9	29.8	35.8
D	1996	14.6	8.2	41.5	37.0
E	1997	50.2	39.8	60.7	44.6

Abbreviation: XRT, radiation therapy.

the whole breast,[15,16] as alternatives to routine whole-breast XRT consisting of 45 to 50 Gy in 25 fractions plus boost irradiation of 10 to 16 Gy in 5 to 8 fractions, may also help alleviate the problems created by long distances to XRT. It is speculated that the significant reduction in time required to receive accelerated breast irradiation (1 to 3 weeks for accelerated partial breast or hypofractionated radiation protocols *v* 6 to 7 weeks for standard external-beam irradiation) will ameliorate some of the logistical problems women currently face in completing BCT.[14,16] However, long-term follow-up studies and larger trials will be required before these technologies replace or are equal to the current standard of care. No population-based studies have yet been performed to evaluate whether these technologies will have an appreciable impact on BCT rates. Finally, additional studies may define certain select subgroups of patients who may not gain a clinically significant benefit from XRT after lumpectomy, thus not requiring XRT for all patients undergoing breast-conserving surgery. A recently published study conducted by the Cancer and Leukemia Group B, Eastern Cooperative Oncology Group, and Radiation Therapy Oncology Group showed that, among women over 70 years of age with small, estrogen receptor–positive tumors, treatment with lumpectomy and tamoxifen alone may constitute an appropriate therapy course.[17]

The results from previous studies on distance to XRT and surgical practice patterns have been variable. Athas et al,[2] who studied women in New Mexico with breast cancer diagnosed between 1994 and 1995, reported that the percentage of women receiving a mastectomy did not vary with XRT travel distance. However, 51% of women living greater than 75 miles from an XRT facility received breast irradiation as part of BCT compared with 82% of women living within 50 miles. In contrast, a study using the Connecticut state registry used services available at the patient's first admitting hospital for breast cancer treatment as a measure of access to therapy. This study showed an association of lower breast-conservation rates with a lack of XRT availability. The Connecticut study did not find a relationship between receiving postlumpectomy XRT and the presence of an XRT facility at the admitting hospital.[7] Nattinger et al[6] reported on 21,135 women diagnosed with breast cancer from 1991 through 1992 from the SEER registry, excluding Hawaii. They noted a significant decrease in breast-conserving surgery for women greater than 15 miles from the nearest XRT facility and a decrease in receiving postlumpectomy XRT for women greater than 40 miles from the nearest XRT facility.[6] In contrast to this population, where only 11% of the affected population lived 15 miles or more away from an XRT facility, 22% of breast cancer patients within our whole-state cohort lived greater than 15 miles away from radiotherapy services. Because certain decisions regarding health care policy and resource allocation are made on a state level, studying the impact of XRT access in a state with historically high mastectomy rates, as in our study, takes on additional relevance.

This study has several limitations. Because this study used straight-line distance calculations, the distance to XRT facility in actual travel distance may well be underestimated in the more mountainous areas of the state. Cancer registry data is primarily limited by incomplete collection of data for outpatient cancer treatments. This limitation is not unique to the VCR. XRT, chemotherapy, and hormonal therapy, which are all integral treatments for breast cancer, are variably recorded in any population-based data set but critical to monitoring quality of care. For example, our data set could not be used to evaluate the appropriateness of care for patients undergoing BCT because it was not possible to distinguish between patients with no and unknown XRT receipt. Our data show that 73% of patients having a lumpectomy did have adjuvant XRT but XRT treatment status is unknown for the other 27%. Because this study does not identify where XRT is received, it is not known whether patients routinely use the closest XRT facility or how far patients commonly travel for XRT. Other potentially meaningful information, such as data about treating hospitals or physicians and data on patient insurance status, was not available from VCR secondary to confidentiality policies or was not adequately reported to be included in the analysis, respectively. Potential inaccuracies and underreporting represent the inherent limitations of all cancer registries. In particular, VCR cautions that cancer cases are likely underreported from areas such as rural Southwest Virginia. However, unless missing patients were predominantly treated with breast conservation, which seems unlikely, this limitation does not dilute the study's findings.

This study also highlights far-reaching issues related to researching barriers to care. Attributing causality or proportional influence to any one factor in assessing access to care poses a significant challenge for health services research. This particular project focused only on one facet of access to care, namely geographic access to XRT. To better estimate the separate influence of physical distance to XRT on breast cancer treatment decisions, a future study will need to incorporate patient socioeconomic information, such as education level and payer status, and physician information, such as specialty training, breast cancer patient volume, and time since training. All of these factors may arguably influence treatment recommendations and choices.

Although the breast-conservation rates observed in Virginia between 1996 and 2000 are now fairly commensurate with national averages,[18,19] the results of this study suggest that opportunities exist to improve care for women residing in areas remote to XRT facilities. This study's findings that women living farther from XRT facilities tend to be diagnosed with larger tumors further underscores the

unmet health care needs, such as breast cancer screening, of underserved populations. Our finding that nonwhite women were more likely to be diagnosed with larger tumors despite, on the whole, living closer to XRT facilities than white women likely has a multifactorial explanation but, to some degree, reflects other barriers to care such as inadequate health insurance coverage. Future studies in monitoring quality care in breast cancer therapy will need to measure factors not commonly found in population-based datasets, such as patient socioeconomic status and treating physician characteristics, in a meaningful way. Linking this information to treatment data in a population-based setting is the next step in better understanding the patterns in breast cancer care.

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Authors' Disclosures of Potential Conflicts of Interest

The authors indicated no potential conflicts of interest.

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