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Original article

Geographic proximity to treatment for early stage breast cancer and likelihood of mastectomy

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ABSTRACT

Purpose: Women with early stage breast cancer who live far from a radiation therapy facility may be more likely to opt for mastectomy over breast conserving surgery (BCS). The geographic dimensions of this relationship deserve further scrutiny.
Methods: For over 100,000 breast cancer patients in 10 states who received either mastectomy or BCS, a newly-developed software tool was used to calculate the shortest travel distance to the location of surgery and to the nearest radiation treatment center. The likelihood of receipt of mastectomy was modeled as a function of these distance measures and other demographic variables using multilevel logistic regression.
Results: Women traveling over 75 km for treatment are about 1.4 times more likely to receive a mastectomy than those traveling under 15 km.
Conclusions: Geographic barriers to optimal breast cancer treatment remain a valid concern, though most women traveling long distances to receive mastectomies are doing so after bypassing local options.

Introduction

Women diagnosed with early stage invasive breast cancer in the United States are typically presented with a choice of mastectomy or breast conserving surgery (BCS) with radiation therapy (RT). The two options have long been established as equally effective in terms of survival.[1–3] Following the National Institutes of Health's 1990 consensus statement that BCS with RT was the preferred treatment for most women, national mastectomy rates fell steadily through 2006.[4,5] In general, lower mastectomy rates are widely used as a positive indicator of care[6] even though some have cautioned this is too simplistic a measure.[7] The long-term downward trend in mastectomy rates may be poised to change as some recent single-institution studies have noted increases in mastectomy rates, apparently driven by increased MRI usage that leads to the identification of additional areas of concern in ipsilateral breast tissue.[8]

Even as mastectomy rates have fallen, strong geographic variations in mastectomy rates have consistently been observed. In 1994, mastectomy rates in the United States among all women diagnosed with stage I and II breast cancer varied regionally from 46 percent in the Northeast to 53 percent in the Pacific to 68 percent in the South.[9] By 2003 mastectomy rates were much lower but the geographic pattern persisted: 30 percent in the Northeast, 38 percent in the Pacific, and 50 percent in the South among Medicare patients.[10] The regional differences persist after adjustment for other significant predictive factors for mastectomy including older age, nonwhite race, lower socioeconomic status, lower density of medical professionals, larger tumor size at diagnosis, and greater number of comorbid conditions. Such differences are not restricted to the United States: a United Kingdom study found that mastectomy rates between 1997 and 2003 across eleven institutions within a single region varied from 25 percent to 45 percent.[11]

Reasons hypothesized for these differences include cultural differences that result in different acceptance of RT, physician bias toward a particular treatment, variations in patient education and

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awareness about the options, and hospital quality and characteristics.[10] Another major factor, and the focus of this paper, is accessibility to treatment, specifically RT.

Both breast conserving surgery and mastectomy consist of a several-hour procedure in an inpatient hospital setting, followed by up to two days of hospital recovery. Radiation therapy additionally requires some five sessions per week for five to seven weeks at either a hospital or stand-alone radiation therapy center. If a radiation facility is prohibitively far from a patient's residence, the need to commute over a long distance or find short-term accommodations can therefore make mastectomy a more attractive alternative. This is magnified by the fact that there are 75 percent more surgical centers within hospitals in the United States (3943) than there are RT facilities (2246).[12,13]

The time-intensive nature of RT may ultimately become less critical of an issue, as various technologies that can deliver radiation dosages in one to five days are revealing promising results in clinical trials.[14,15] But unless and until this technology is widely adopted, geographic disparities are likely to persist.

A strong relationship between RT accessibility and mastectomy rates in the United States has been consistently noted. A Virginia-based study found that mastectomy rates between 1996 and 2000 increased monotonically with distance to RT, from 43 percent for those living less than 10 miles away to 58 percent for those over 50 miles.[16] During their study period, a new RT facility was opened in a rural setting, and mastectomy rates in this area dropped from 61 percent to 45 percent. Comparable results have been found in Florida[17] and Michigan.[18] A study of SEER registries identified a general rural–urban difference nationally,[19] while a New Mexico study found that receipt of RT after BCS was also strongly correlated with distance.[20]

The objective of our study was to assess the relationship between breast cancer surgery and geographic access to RT through two measures of accessibility: distance to the nearest RT facility and distance to location of surgery. These correlated, but distinct, measures help distinguish between women who travel longer distances out of necessity or as a result of other factors, such as choice, referral networks, or the need for specialized care.

Materials and methods

Early stage breast cancer cases (Collaborative Stage-derived SEER Summary Stage 2000 localized cases)[21] among women diagnosed between 2004 and 2006 from ten different state cancer registries that volunteered to participate in this project (Arkansas, California, Idaho, Iowa, Kentucky, New Hampshire, New Jersey, New York, North Carolina, and Oregon) were compiled. Together these registries represent 30 percent of the United States population. Cases were limited to women who had either breast conserving surgery (*FORDS* codes 20–24) or mastectomy (codes 30–80) as their most definitive surgery ($n = 104{,}730$).[22] Radiation treatment data were also available, but because of differential reporting by state were determined not to be of sufficient quality to use in the analysis.

Two distance measures were calculated for each patient. The first was the travel distance via roads from the road nearest the centroid of the patient's census tract to the nearest RT location, used as a measure of potential access to RT. The second was the travel distance via roads from the patient's residence to the location of surgical treatment, used as a measure of realized access to cancer care. The use of census tract centroids in the first measurement was a necessary consequence of how the data were provided to us by the participating registries. Compared with using residential addresses, this adds random spatial error averaging 1 km nationwide. For patients whose diagnosis and treatment spanned multiple facilities, the minimum distance from among the candidate facilities was used.

Radiation treatment locations were obtained from a comprehensive nationwide database as of 2004–2005.[12] For 8 percent of the cases, exact residential locations were not available and the ZIP code or municipal centroid was used, an additional small source of random spatial error. Distances were calculated using the Shortest Path calculator developed for this project at the University of Southern California GIS Research Laboratory[23] and grouped into seven categories (<15 km, 15–30 km, 30–45 km, 45–60 km, 60–75 km, 75–100 km, 100+ km). The A* shortest path search algorithm[24] was used for computing shortest travel distance path for each patient based on an in-memory directed graph representation of the NAVTEQ NavStreets street network (NAVTEQ, Chicago, IL). Euclidean distance between starting and ending locations was used as the A* heuristic, which allowed this algorithm to outperform the computation speed of the classic Dijkstra shortest path search.[25] Starting and ending locations for the shortest path within the street network graph were determined through a nearest neighbor search constrained by physical and logical restrictions of network nodes and edges, for example, gates, highway on-ramps and exits, one way streets, and turn restrictions.

The likelihood of receiving breast conserving surgery versus mastectomy was modeled using multilevel logistic regression[26] using PROC GLIMMIX in SAS Version 9.2 (SAS Institute, Cary, NC, code available from the authors). Two models were developed, one using each distance measure. In addition to the distance measure, fixed effects in the model included age, year of diagnosis, race, ethnicity, census tract-level household poverty rate and rural/urban status, and whether the tumor was a person's first primary tumor. Each of these variables was selected because of its potential to confound the relationship between treatment and distance. Poverty rate was based on the 2000 United States census and rural/urban status was based on Rural Urban Commuting Area (RUCA) codes developed by the United States Department of Agriculture.[27] The 33 published RUCA codes were collapsed into 3 categories based on commuting proximity to metropolitan area cores (central places with >50,000 population), micropolitan area cores (central places of 10,000–49,999 population), or neither of these. State of residence was included as a random effect. Cases were excluded if county or census tract was unknown, if the census tract poverty rate was undefined (because too few households were sampled in 2000), if there was an invalid county/tract combination, or for any other reason for which a shortest path could not be calculated. These exclusions reduced the number of eligible cases in the study by 4 percent to 100,491. The unadjusted probability of receiving mastectomy versus breast conserving surgery was also estimated for each variable. We were further interested in assessing the probability of mastectomy for patients who traveled more than 60 km for surgery but who lived within 30 km of a radiation treatment center. We termed these "bypass patients" as they were not utilizing the nearest treatment resource. This term has been used elsewhere to describe those who seek care at locations outside of their own community, typically at large, urban, nationally-recognized hospitals.[28]

Results

Without adjustment for demographic and diagnostic characteristics, increasing distance to nearest RT was generally associated with increasing likelihood of mastectomy, from 32.2 percent less than 15 km to 44.0 percent between 75 and 100 km; above 100 km, the mastectomy rate dropped to 37.7 percent (Table 1). For distance to surgery, likelihood of mastectomy increased monotonically, from

Table 1
General characteristics of breast cancer cases included in the study.

Measure	Categories	Cases	% Receiving Mastectomy
Overall		104,730	33.4
Distance to surgical facility (km)	0–15	62,872	31.5
	15–30	21,303	34.8
	30–45	7687	36.4
	45–60	3614	37.9
	60–75	1821	38.9
	75–100	1534	40.9
	100+	1934	43.1
Distance to nearest radiation treatment facility (km)	0–15	76,559	32.2
	15–30	15,106	34.0
	30–45	5640	39.3
	45–60	2876	39.0
	60–75	1472	43.3
	75–100	997	44.0
	100+	657	37.1
Age (years)	<50	21,573	37.6
	50–64	36,970	31.0
	65+	46,187	33.2
Race	White	89,884	32.8
	Black	8027	32.6
	API	5631	42.3
	AI/AN	271	40.2
	Unknown	917	35.7
Ethnicity	Hispanic	7964	34.7
	Non-Hispanic	96,766	33.3
State	Arkansas	2798	40.4
	California	39,118	33.5
	Idaho	1437	32.8
	Iowa	4131	43.1
	Kentucky	4849	41.0
	New Hampshire	1897	27.4
	New Jersey	11,293	29.0
	New York	23,484	28.4
	North Carolina	10,553	38.2
	Oregon	5170	37.5
Poverty rate in census tract of residence in 2000 (%)	0–<5	31,494	30.9
	5–<10	31,738	32.7
	10–<20	28,345	35.6
	20+	13,153	35.8
Commuting proximity	Neither	7920	40.0
	Micropolitan	8867	38.2
	Metropolitan	86,558	32.2
Tumor sequence number	First or only tumor	86,710	30.7
	2nd or subsequent tumor	18,020	46.2
Diagnosis year	2004	34,280	34.3
	2005	34,681	32.6
	2006	35,769	33.2

31.5 percent less than 15 km to 43.1 percent above 100 km. These relationships were maintained after adjustment (Table 2). There was a generally increasing likelihood of mastectomy with increasing distance to nearest RT, diminishing at the highest distance category, and a monotonically increasing likelihood of mastectomy with increasing distance to surgery. Overall, distance to surgery showed a somewhat larger effect size than distance to nearest RT. Other characteristics with a high likelihood of mastectomy under either model included residence in certain states, age under 50, Asian or Pacific Islander race, and whether the tumor was the second or subsequent tumor. The differences by state were dramatic; relative to New Hampshire, residents of five states (Arkansas, Kentucky, Iowa, North Carolina, and Oregon) were 1.5 times as likely to receive mastectomy, and in Iowa, the likelihood was doubled. The remaining characteristics (ethnicity, poverty rate, commuting proximity, and diagnosis year) had a relatively small impact on the likelihood of mastectomy, though some were statistically significant due to the very large sample.

Of the 2678 patients defined as bypass patients (>60 km for surgery and <30 km from nearest RT), 42.2 percent received mastectomy, an odds ratio of 1.27. Bypass patients far outnumber those with poor geographic access; there are 1345 patients more than 60 km from both their surgery location and nearest RT. This remains true even for more inclusive definitions of bypass patients and patients with poor geographic access.

Discussion

These results strongly suggest that geographic barriers influence treatment for early stage breast cancer, with roughly one-third greater likelihood of mastectomy among women who travel more than 75 km versus under 15 km, whether measured by distance to surgery or distance to the nearest RT facility. Distance to surgery was the more robust measure, as this measure captured the influence of both poor geographic access and bypass patients. Prior to the study, we had hypothesized the bypass patients to be more inclined to follow the preferred guideline of BCS with radiation, but the opposite was true. This is likely due to the multifaceted characteristics of this group, including patients who elect to travel long distances to seek the best (or perceived best) care, those whose prior medical histories call for more specialized care, those who were referred from smaller to larger cancer centers for any number of reasons, and perhaps even those whose insurance coverage dictated longer travel. It is also possible that these women differed in tumor characteristics such as tumor size or hormone receptor status, even though all were diagnosed at early stage. Unfortunately, data currently collected by central cancer registries do not allow making these distinctions. This may be possible in the future given expanded data collection requirements in recent years.[29] We also explored the possibility that women traveling long distances for a mastectomy were more likely to have had a previous tumor treated with BCS at a local hospital. While examples of this could be identified in the data, the number was very small, and excluding these cases had a negligible effect on the results.

Researchers who have investigated why patients seek care outside their own communities for conditions other than cancer have found that hospital reputation, volume, quality of facilities and equipment all attract patients from afar, as do younger patient age, higher income, degree of complexity of the desired procedure, and patterns of referral.[30–32] It is reasonable to expect that these findings would extend to cancer care.

Our analysis was limited by the data that central cancer registries either do not collect or were unable to provide. These include a lack of data on prior medical history or comorbid conditions as well as data on tumor characteristics such as tumor size and hormone receptor status, all of which may help explain the treatment patterns of bypass patients. Incomplete reporting of radiation data further limited the scope of our analysis. We also lacked data on patient insurance coverage, contracting arrangements between hospitals and insurers, and hospital characteristics such as volume, specialization, reputation, and waiting time, all of which can influence or dictate the location of treatment. Hospital-insurer arrangements may be especially relevant in areas with high managed care penetration, particularly in areas with managed care-owned facilities, such as the Kaiser Permanente-owned hospitals in California. It is true, however, that patients seeking treatment outside of their communities typically bypass many potential facilities while traveling between cities, not just those that may pose an immediate local barrier. That is, while insurance considerations may limit patient options within a city like Fresno, California, they are unlikely to obligate them to travel all the way to Los Angeles. The fact that many patients do make such a journey suggests that other factors are involved.

Table 2
Model-adjusted odds ratios and 95% confidence intervals for predictors of receipt of mastectomy.

Variable	Categories	Model 1: Surgery proximity	Model 2: Nearest radiation facility
Distance (km)	0–<15	1.00 (reference)	1.00 (reference)
	15–30	1.17 (1.13–1.21)	1.05 (1.01–1.09)
	30–<45	1.21 (1.15–1.27)	1.17 (1.09–1.25)
	45–<60	1.23 (1.14–1.32)	1.08 (0.98–1.18)
	60–<75	1.26 (1.14–1.39)	1.33 (1.18–1.50)
	75–<100	1.34 (1.21–1.50)	1.43 (1.23–1.65)
	100+	1.43 (1.30–1.57)	1.12 (0.93–1.34)
Age (years)	65+	1.00 (reference)	1.00 (reference)
	50–64	0.93 (0.90–0.96)	0.95 (0.92–0.98)
	<50	1.31 (1.26–1.36)	1.34 (1.29–1.39)
Race	White	1.00 (reference)	1.00 (reference)
	Black	1.01 (0.96–1.06)	1.00 (0.94–1.05)
	Asian/Pacific Islander	1.71 (1.61–1.81)	1.70 (1.60–1.80)
	American Indian/Alaska Native	1.17 (0.90–1.51)	1.18 (0.91–1.52)
	Unknown	1.28 (1.10–1.48)	1.29 (1.11–1.49)
Ethnicity	Non-Hispanic	1.00 (reference)	1.00 (reference)
	Hispanic	1.17 (1.11–1.24)	1.16 (1.11–1.23)
State	Arkansas	1.59 (1.46–1.73)	1.65 (1.51–1.79)
	California	1.31 (1.21–1.42)	1.35 (1.25–1.46)
	Idaho	1.28 (1.17–1.40)	1.29 (1.17–1.41)
	Iowa	2.00 (1.84–2.17)	1.97 (1.82–2.14)
	Kentucky	1.83 (1.69–1.98)	1.88 (1.74–2.04)
	New Hampshire	1.00 (reference)	1.00 (reference)
	New Jersey	1.11 (1.03–1.21)	1.15 (1.06–1.24)
	New York	1.07 (0.99–1.15)	1.10 (1.02–1.19)
	North Carolina	1.63 (1.51–1.76)	1.69 (1.56–1.83)
	Oregon	1.60 (1.48–1.74)	1.62 (1.50–1.76)
Poverty rate in census tract of residence in 2000 (%)	20+	1.00 (reference)	1.00 (reference)
	10–<20	0.94 (0.90–0.99)	0.95 (0.90–0.99)
	5–<10	0.86 (0.82–0.90)	0.88 (0.84–0.92)
	<5	0.86 (0.82–0.90)	0.88 (0.83–0.92)
Commuting proximity	Metropolitan	1.00 (reference)	1.00 (reference)
	Micropolitan	1.12 (1.07–1.18)	1.11 (1.06–1.17)
	Neither	1.06 (1.00–1.13)	1.06 (0.99–1.14)
Tumor sequence	2nd or subsequent tumor	1.00 (reference)	1.00 (reference)
	First or only tumor	0.48 (0.47–0.50)	0.48 (0.46–0.50)
Diagnosis year	2006	1.00 (reference)	1.00 (reference)
	2005	0.97 (0.94–1.00)	0.97 (0.94–1.00)
	2004	1.06 (1.02–1.09)	1.05 (1.02–1.09)

Still other limitations applied to the calculation of distances. For patients with multiple reporting sources, we potentially underestimated the distance to surgery and potentially misclassified distance due to imprecise case geocoding or any omitted RT facilities. Each of these would tend to underestimate the magnitude of the distance effect.

Despite all of these limitations, this study does augment previous, smaller studies that have found that geographic distance is a fundamental element of patterns of cancer care. Indeed, this has been a recurring theme in studies of health care generally. A wide range of studies has consistently found that patients living in more remote locations are less likely to receive treatment at all or treatment that conforms to current recommended standards of care, and are more likely to present with more advanced illness.[33–37] Our study finds this relationship to be reflected in treatment for early stage breast cancer in the United States. The time and effort required to commute 25–35 times to receive radiation therapy undoubtedly influences some women to opt for mastectomy over breast conserving surgery.

While the lack of options for breast cancer patients living in rural areas has been well-studied, the experiences of the much larger number of women bypassing treatment options within their own community, and their tendency to receive mastectomy, have received less attention. While this paper was unable to divine the contributory causes behind this pattern, it certainly is deserving of further investigation. One way to understand treatment choice and location, of course, is to ask cancer patients themselves,[38] and to that end cancer registry data aided by methodological tools such as the Shortest Path calculator can readily identify an appropriate and geographically representative cohort.

Ethnical approval

This research used previously collected, deidentified data and did not involve any contact with human subjects.

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Conflict of interest statement

The authors declare no conflicts of interest.

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