Published in final edited form as:

J Surg Res. 2017 May 01; 211: 196–205. doi:10.1016/j.jss.2016.11.065.

Institutional variation in surgical care for early-stage breast cancer at community hospitals

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Abstract

Background—There is significant institutional variation in the surgical care of breast cancer, and this may reflect access to services and resultant physician practice patterns. In previous studies, specialty care has been associated with variation in the operative treatment of breast cancer but has not been evaluated in a community setting. This study investigates these issues in a cohort of 59 community hospitals in the United States.

Materials and methods—Data on patients receiving an operation for breast cancer (2006–2009) in a large, geographically diverse cohort of hospitals were obtained. Administrative data, autoabstracted cancer-specific variables from free text, and multiple other data sets were combined. Polymotous logistic regression with multilevel outcomes identified associations between these variables and surgical treatment.

Results—At 59 community hospitals, 4766 patients underwent breast conserving surgery (BCS), mastectomy, or mastectomy with reconstruction. The older patients were most likely to receive mastectomy alone, whereas the younger age group underwent more reconstruction (age <50), and

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Reprints will not be available from the authors.

Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in the article.

BCS was most likely in patients aged 50–65. Surgical procedure also varied according to tumor characteristics. BCS was more likely at smaller hospitals, those with ambulatory surgery centers, and those located in nonmetropolitan areas. The likelihood of reconstruction doubled when there were more reconstructive surgeons in the health services area ($P = 0.02$). BCS was more likely when radiation oncology services were available within the hospital or network ($P = 0.04$).

Conclusions—Interpretation of these results for practice redesign is not straightforward. Although access to specialty care is statistically associated with type of breast surgical procedure, clinical impact is limited. It may be more effective to target other aspects of care to ensure each patient receives treatment consistent with her individual preferences.

Introduction

The surgical treatment of early-stage breast cancer epitomizes preference-sensitive decision-making. There are three options, none of which is clinically superior: (1) breast conserving surgery (BCS); (2) mastectomy with reconstruction; and (3) mastectomy alone. Multiple randomized controlled trials with significant long-term follow-up have demonstrated the effectiveness of BCS when combined with adjuvant radiation relative to mastectomy in terms of survival.^{1–4} After accounting for clinical indications, the decision for surgical treatment should reflect the preferences and values of an individual patient, including such issues as cosmetic outcome, operative recovery time, the logistics of adjuvant radiation, and the difference in local recurrence rates, among others. In a 2005 study, over 75% of patients reported that they either made the decision or participated in the decision-making regarding the surgical management of their newly diagnosed breast cancer⁵; however, in a more recent study, less than half of patients (48.6%) reported being asked their treatment preference for surgery.⁶ This suggests that factors other than patient preference drive this decision for type of breast cancer surgery.

Significant variation in how breast cancer surgical care is delivered has been described across geographic region,^{7–9} health care providers^{10–12} (including institutional and surgeon-level variation), and patient sociodemographics.^{13–15} The etiology of these observed differences in care is likely multifactorial and complex but cannot be explained by patient preference alone. A thorough understanding of the underlying factors is critical to differentiate appropriate variation (due to patient preference and/or clinical factors) from unwanted variation representing disparities in care and therefore warranting intervention.

Previous studies have identified access to requisite specialty care, namely reconstructive surgery and adjuvant radiation, as one factor that may contribute to variation in the surgical treatment of breast cancer.^{16–20} Community hospitals provide approximately 75% of the surgical care for breast cancer in the United States.²¹ A thorough understanding of practice patterns in this understudied sector of the health care system is necessary to reduce provider-based variation in the surgical treatment of early-stage breast cancer and ensure that each patient is treated in a manner consistent with her preferences and values. To that end, we sought to investigate the degree of variation across hospitals and the influence of access to reconstructive surgery and radiation oncology in a geographically and structurally diverse cohort of community hospitals.

Methods

Cohort identification

The Institute for Health Metrics (IHM) is a nonprofit organization that collects data from existing hospital information systems, including both structured data (e.g., administrative data or laboratory values) and unstructured clinical data (i.e., free text). Table 1 presents a description of the hospitals that partner with IHM. The data are primarily collected to aid partner institutions in quality reporting and improvement; however, deidentified data are also available for research. Women with a diagnosis of breast cancer who had a breast or axillary procedure between January 2006 and December 2009 at a hospital that was a business partner with IHM were identified using appropriate International Classification of Diseases, Ninth Revision and Current Procedural Terminology codes ($n = 6098$). Access to structured administrative and clinical data as well as the free text in electronic health records was available. The cohort was limited to patients in whom a breast procedure was performed, and an electronic operative note was available. The final analytic cohort included 5194 patients with 11,022 encounters across 59 hospitals.

Preparation of analytic data set

Existing structured variables were compiled into an Oracle database that was converted to SAS for data analysis. All patient-level structured data were merged and transformed; quality checks were performed, and any identified inconsistencies were reconciled. For these 5194 patients, 103,106 free-text medical records were identified and isolated as one XML file per patient.

Linkage with other existing data sets for provider and institutional factors

Patient zip code was used to link to the US Census Data from 2000 to obtain patient-level variables on socioeconomic status. The National Provider Identifier file was linked to IHM administrative data and used to calculate the number of plastic or reconstructive surgeons who submitted a claim from each hospital. For those hospitals that did not have National Provider Identifier numbers available, surgeons were identified as plastic or reconstructive surgeons based on an analysis of their case mix in the full IHM data set.

The Area Resource File provided the density of radiation oncologists and plastic or reconstructive surgeons in the Health Service Area (HSA) for each institution. The Radiological Physics Center database, a previously published database of radiation therapy facilities in the US²² was updated and expanded. ArcGIS and SAS software were used to geocode and calculate the distance a patient traveled to the closest radiation facility based on patient zip code and the street address of each radiation facility in the United States. Finally, each institution was linked to data from the American Hospital Association to obtain structural characteristics. After these linkages, both the structured data and free-text documents were deidentified prior to analysis.

Extraction of key variables from free text

An open source data import module mapped XML-formatted data into software that was used to classify documents and extract key variables. The Automated Retrieval Console was

used for all document-level classification tasks.^{23–28} Each document in a 1.5% ($n = 1597$) random sample of the available free-text documents was reviewed by two trained abstractors and classified as breast cancer operative notes, clinic notes, pathology notes, or not relevant. Operative notes were further classified as breast cancer diagnostic, breast cancer therapeutic, or not applicable. Any disagreements were adjudicated by a third investigator. The final adjudicated sample was used for computer learning. Interrater reliability between the two manual abstractors and agreement between the adjudicated data set and the computer extracted data set were calculated using a kappa coefficient.

A similar abstraction and adjudication process was used to develop a rule-based approach to the automated extraction of five key cancer-specific variables from the free text documents: T stage, N stage, estrogen receptor status, progesterone receptor status, and Her2 neu status. Standardized and consistent definitions were developed for each data element. A previously developed and open-source software, known as Knowtator, allowed reviewers to annotate multiple variables in the free-text documents. Two independent reviewers abstracted each data element independently with adjudication by a third reviewer. Based on algorithms developed from the training set, rule-based patterns were then programmed for the automated extraction of individual data elements from the free text of the isolated pathology and clinic notes. Performance was evaluated as recall, precision, and harmonic mean or “f-measure” using the validation set as the gold standard.

Extraction of cancer-specific variables was performed at the individual document or encounter level. An algorithm was developed to assign one value per patient, and inconsistencies were manually reviewed. These data were then merged with the existing structured SAS data set.

Data analysis

Of the 5194 patients, 5186 patients underwent a definitive breast procedure. This was then limited to patients ($n = 4766$ patients from 59 hospitals) with at least one therapeutic breast operative report identified (Figure). As the first therapeutic procedure is most reflective of surgical decision-making, we identified this procedure for each patient. Basic descriptive statistics were performed for both patient and institutional characteristics. The primary outcome was a categorical variable for type of surgery performed—BCS, mastectomy alone, or mastectomy with reconstruction. The primary variables of interest measured access to specialty care and included (1) number of plastic surgeons per 100,000 female population (HSA level); (2) number of plastic surgeons per 100 annual breast procedures (institution level); (3) number of radiation oncologists per 100,000 female population (HSA level); (4) availability of radiation oncology services at the hospital or system level; and (5) mean distance to nearest radiation facility for all patients receiving a therapeutic breast procedure at a given institution, based on each patient’s zip code.

Bivariate logistic regression was performed to assess the significance of each of the primary predictors as well as the *a priori* patient and institution-level variables identified in Table 1. All primary predictors and any other variables with a significant association (defined as $P < 0.1$) on bivariate analysis was considered for inclusion in the final multivariable modeling. Polymotous multinomial logistic regression was used to calculate the adjusted odds of

receiving each procedure. This was converted to an adjusted probability to aid in clinical interpretation. All presented *P*-values are adjusted. Analyses were performed using SAS v. 9.3.

Results

Of the 4766 patients from 59 hospitals who underwent at least one therapeutic procedure, 2888 patients had BCS (61%) as the first therapeutic procedure, 1350 had mastectomy alone (28%), and 528 had mastectomy with reconstruction (11%). This translates to a 28% rate of reconstruction among the 1878 patients who had a mastectomy. Table 1 depicts the patient and institutional characteristics of the cohort.

Classification of breast cancer-related document type

The manual abstractor interrater reliability (IRR) was 0.96 for identification of pathology reports, 0.86 for clinic notes, and 0.91 for operative notes. Computer performance was strong with recall of 0.95, 0.96, and 0.91; precision of 0.95, 0.88, and 0.85; and f-measure of 0.94, 0.91, and 0.87 for pathology, clinic, and operative notes, respectively. A total of 2055 pathology reports, 25,714 clinic notes, and 15,131 operative reports were ultimately identified. The computer identification of therapeutic operative notes showed similarly high performance (0.96 recall, 0.93 precision, and 0.94 f-measure).

Concept-level data extraction from individual documents

IRR between manual reviewers for of individual data elements from clinic notes was similarly high and ranged from 0.91 for Her-2-neu status to 1.00 for T stage, estrogen receptor status, and progesterone receptor status. IRR for pathology results was poorer ranging from 0.38 for N stage to 0.91 for PR status. Automated natural language processing performance of recall, precision, and f measure are presented in Table 2 for the concept-level data abstraction. At least one variable was abstracted on 2708 patients, and 2146 patients had abstraction of all five variables.

Patient factors associated with type of surgical procedure

The older patients (age >65) were most likely to receive mastectomy alone, whereas mastectomy with reconstruction rates were highest in the younger age group (age <50), and BCS was most likely in the middle age group (age 50–65), after adjusting for other significant predictors (See Table 3). Surgical procedure also varied according to tumor characteristics as one would predict; however, caution must be used in interpreting these data given the significant missingness of these cancer-specific variables (See Table 1). Patients with larger tumors and advanced nodal stage were more likely to undergo mastectomy alone, compared to patients with smaller tumors and no lymph node involvement, who were more likely to undergo BCS ($P < 0.001$). Rates also varied by estrogen receptor, progesterone receptor, and her2 neu status.

Institutional factors associated with type of surgical procedure

The characteristics of the institution where the operation occurred also influenced the type of operation with higher rates of BCS at smaller hospitals, those with ambulatory surgery

centers, and those located in a nonmetropolitan area (See Table 3). Mastectomy with reconstruction was highest in larger hospitals in metropolitan areas.

Table 4 presents the adjusted probabilities of receiving each operation based on our primary predictors. The likelihood of mastectomy with reconstruction doubled (7.2% *versus* 3.6%, $P = 0.02$) when there were more than four plastic surgeons per 100,000 female population in the HSA in which a hospital was located. The adjusted probability of BCS (66% *versus* 62%) was higher, and mastectomy alone (27% *versus* 34%) was lower when radiation oncology services were available at the hospital, network, or system level compared to contracted with another entity or not available ($P = 0.04$). There was no statistically significant association between the number of plastic surgeons at the institutional level, radiation oncologists at the HSA level, or mean distance to a radiation facility.

The analysis was repeated for the 2146 patients for whom breast cancer–specific variables were available. A similar pattern was identified, but results were underpowered and did not reach significance.

Discussion

Breast cancer is the most common malignancy among U.S. women, and surgery is a mainstay of treatment, yet surgical decision-making is complex. The surgical care of breast cancer patients is currently provided in a variety of practice settings. Although the choice of procedure ideally represents the preference of the patient within clinical constraints, it may also be influenced by the surgeon or the institution, reflecting variations in the physician's own preferences or the availability of key resources. We investigated one hypothesis that access to specialty care would correlate with the type of operation preferentially performed. We found a small but statistically significant association between several measures of specialty care and the type of operation for breast cancer, with the adjusted probability of mastectomy with reconstruction among all breast cancer patients undergoing a definitive breast procedure doubling (7.2% *versus* 3.6%) in areas with more plastic or reconstructive surgeons and adjusted probability of BCS decreasing in institutions without available radiation oncology services; however, the effect was smaller than anticipated. In addition, there was no observed association between our other measures of access to specialty care (i.e., number of plastic surgeons per 100 annual breast procedures, number of radiation oncologists in the HSA, and the mean distance to the nearest radiation facility) and type of surgical procedure.

Our results are consistent with previous studies demonstrating a small but statistically significant association between the availability of reconstructive surgery and radiation oncology and the type of operation performed for early-stage breast cancer.^{16–20} Preoperative discussion with a radiation oncologist and proximity to a radiation facility have been previously associated with an increased likelihood of BCS in a patient-level analysis.¹⁶ At the institutional level, a higher likelihood of mastectomy with reconstruction was observed in hospitals with more reconstructive surgeons on staff or where patients had to travel longer distances for radiation therapy, whereas patients treated at hospitals where reconstruction-prolonged waiting times for surgery had a lower likelihood of mastectomy

with reconstruction.²⁰ Although these results are statistically significant, the strength of the association and lack of consistency across measures suggest this may not be the highest impact target for interventions.

A major strength of our study is the linkage of a novel data source through the IHM to a number of publicly available data sets. IHM is a nonprofit organization that has partnered with community hospitals to retrieve data from existing information systems. Its primary purpose is to support member hospitals in health care operations, but deidentified data are also available to health services' researchers, providing a unique opportunity to study health care in community hospitals, an understudied sector of the U.S. health care system where the majority of breast surgery is performed. The wide variety of institutional characteristics available in this database, including size (20–800 beds), location (urban, suburban, and rural), and geographic region, makes it ideal for studying the influence of such characteristics on practice patterns.

This study demonstrates the potential role of the vast amount of data in electronic medical records in advancing the discipline of health services' research in cancer, particularly practice pattern analysis and comparative effectiveness research. For breast cancer, data elements such as cancer stage and tumor characteristics are critical to many studies. We attempted to apply standard approaches to natural language processing in a large and heterogeneous data set from a diverse set of hospitals. We were able to reliably identify pathology, clinic, and operative notes and extract cancer-specific data elements when notes were present.

However, such notes were only available on a small subset of our patients. This limitation is attributable to the structure and procedures of the IHM data source. Data are transferred from participating hospitals to IHM in a one-time data pull within 5 or 7 d of an operation or discharge. This window may be too short to capture many pathology reports, particularly in smaller institutions where pathologic review of breast cancer specimens may be outsourced. Furthermore, data transferred to IHM come from the hospital EMR and may not include clinic notes unless clinician offices use the same EMR system. IHM is addressing these issues to increase the value of this important data source for future health services research projects. This finding also illustrates the critical role of interoperability, and integration at the policy-level EMR continues to rule out across the United States. To investigate the impact of this limitation, we performed a secondary analysis on the subset of patients without missing data and obtained similar results to those from the entire cohort.

Our study has other limitations as well. This is a retrospective study reliant on the secondary use of data that have been collected for other purposes, and thus, we are limited to the available data elements. The integration of multiple data sources provided variables to investigate our primary question of interest as well as information about the physician and institution, but important patient-level variables such as smoking history and breast cancer risk factors were not available. Another limitation is the lack of diversity in the patient-level characteristics. For example, 87.7% of patients in this analysis are Caucasian. Unfortunately, this limitation is not unique to our data set. According to the Surveillance, Epidemiology and End Results data, 8.6% of patients are black, 9.4% are other race/ethnicity, and the

remainder (>80%) are non-Hispanic white. In the National Cancer Data Bank, 79% are Caucasian.²⁹

Interpretation of these results, as well as how and if breast cancer surgery practice should be redesigned, is not straightforward. Providers may be adapting their surgical recommendations and presentation of the risks-benefit profiles for the different surgical options in the treatment of breast cancer based on the availability of the requisite specialists to ensure timely and effective care. However, in addition to timely and effective, the Institute of Medicine includes “equitable” as one of its six tenets of quality health care.³⁰ The availability of and access to specialty care appears to have a statistically significant but clinically modest impact on the type of procedure performed for breast cancer. At this time, this impact does not appear significant enough to warrant policy changes for breast cancer surgery.

The institutional variation we observed in our study supports prior observations that other provider-related factors have a strong influence on decision-making for breast cancer surgery. Hawley *et al.* showed a wide range of surgeon rates of BCS (27%–85%) and postmastectomy reconstruction (6%–84%).¹⁰ Although many states have laws requiring that surgeons discuss both mastectomy and BCS, patient reports suggest this does not always happen. In a survey-based study with 440 respondents by Lee *et al.*, 90% of patients reported that their providers discussed partial mastectomy as an option, whereas significantly fewer (68%) reported a discussion of mastectomy as an option, and only 59% reported a discussion of both options.⁶ Our hypothesis was that physicians may be framing these options in light of variable access to reconstructive and radiation oncology services. Our results show that the surgical treatment of breast cancer is only modestly associated with access to necessary specialty care (reconstructive surgery and radiation oncology), suggesting that other targets may lead to more effective and efficient interventions to ensure each patient is getting care that is consistent with her individual preferences. Future research should focus on ensuring a balanced presentation of the options for the surgical treatment of breast cancer in general, through improved communication between breast cancer patients and their providers and the development and implementation of standardized materials, such as electronic decision aids to educate both patients and providers.

Acknowledgments

This project was supported by the National Cancer Institute (RC1CA144705-03). Support for individual investigators also included the American Surgical Association Foundation (C.C.G.) and NIH training grants T32 CA009535-23 (C.M.D.), T32 DK00754-12 (Y.-Y.H.), and T32 CA090217 (M.R.D.). The authors would like to acknowledge the Massachusetts Veterans Epidemiology Research and Information Center (MAVERIC) for their support.

Authors' contributions: C.M.D. contributed for conception, design, data collection, analysis, writing, review and revision, and funding. S.R.L. contributed for design, data interpretation, and analysis. M.R.D. performed data interpretation, analysis, and writing. Y.-Y.H. contributed for design, data collection, analysis, writing, and review. S.R.P.Q. contributed for analysis, writing, review, and revision. A.K. contributed for design and data interpretation. L.D. contributed for design, data interpretation, and analysis. C.C.G. contributed for conception, design, analysis, writing, review and revision, and funding.

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Figure.
Flowchart outlining the process of identifying the final analytic cohort of patients.

Table 1

Description of cohort.

Patient characteristics		<i>n</i> = 4766	%	Hospital characteristics		<i>n</i> = 59	%
Age	Number of plastic surgeons per 100 annual breast procedures						
<50	1058		22.2	0–2		25	42.4
50–65	1961		41.2	2–6		13	22.0
>65	1747		36.6	>6		21	35.6
Race	Plastic surgeons per 100,000 female population						
Caucasian	4181		87.7	4 or less		26	44.1
Black/AA	280		5.9	More than 4		31	52.5
Hispanic	91		1.9	Missing		2	3.4
Asian	79		1.7				
Other	51		1.1				
Unknown	84		1.8				
Census median income	Radiation oncology services available						
Quartile 1	\$42088			Hospital/network/system		29	49.2
Quartile 2	\$51372			Joint venture/none		25	42.4
Quartile 3	\$65696			Missing		5	8.5
Quartile 4	\$116053						
Census educational level	Mean distance to nearest radiation						
Low education (<50% of population has > high school)	1811		38.0	<5 miles		6	11.5
				5–10 miles		19	36.5
				10–20 miles		19	36.5
				20 miles or more		8	15.4
Tumor stage	Radiation oncologists per 100,000 female population						
T0	104		2.2	4 or less		33	55.9
T1	825		17.3	More than 4		24	40.7
T2	364		7.6	Missing		2	3.4
T3	92		1.9				
T4	70		1.5				

Patient characteristics	n = 4766	%	Hospital characteristics	n = 59	%
TX	17	0.4			
Missing	3294	69.1			
Nodal stage			Total bed size		
N0	841	17.7	0–149	18	30.5
N1	328	6.9	150–245	20	33.9
N2	93	1.9	>245	19	32.2
N3	38	0.8	Missing	2	3.4
NX	94	2.0			
Missing	3372	70.8			
Estrogen receptor			Total # of operating rooms		
Positive	1359	28.5	Less than 10	26	44.1
Negative	375	7.9	10 or greater	25	42.3
Missing	3032	63.6	Missing	8	13.6
Progesterone receptor			Nurse staffing ratio		
Positive	1160	24.3	<2.5	11	18.6
Negative	496	10.4	2.5–3.5	23	39.0
Missing	3110	65.3	3.5 and more	23	39.0
			Missing	2	3.4
Her2 neu			Approval/accreditation		
Positive	279	5.9	JCAHO	49	86.0
Negative	1029	21.6	CoC	39	68.4
Missing	3458	72.6	ACGME residency	14	24.6
			Critical access	8	14.0
First therapeutic procedure			Ambulatory surgery		
BCS	2888	60.5	Hospital	13	24.1
Mastectomy	1333	11.4	Network/system	4	7.4
Mastectomy + reconstruction	545	27.9	Joint venture	5	9.3
			None	32	59.3
Charlson comorbidity			Chemotherapy administered		

Patient characteristics	n = 4766	%	Hospital characteristics	n = 59	%
0	3816	80.1	Hospital	46	85.2
1	690	14.5	Network/system	0	0
2 or more	260	5.4	Joint venture	1	1.9
			None	7	12.9
			RUCA code		
			Metro area	12	20.3
			Nonmetro area	45	76.3
			Missing	2	3.4

RUCA = rural urban commuting area.

A priori variables of interest were identified at both the patient and hospital level. This table shows the number and percent of the entire cohort represented by each category for each of these variables.

Table 2

Computer performance in the identification of key data elements from the free text of electronic medical records.

Source	Recall	Precision	f-Measure
Clinic notes			
T stage	1.00	1.00	1.00
N stage	1.00	0.92	0.96
Grade	1.00	0.75	0.86
ER status	0.86	0.95	0.90
PR status	0.90	1.00	0.95
Her2 neu status	0.84	1.00	0.89
AJCC stage	0.95	0.88	0.91
Pathology reports			
T stage	0.87	1.00	0.93
N stage	0.92	1.00	0.96
Grade	0.97	0.79	0.87
ER status	0.90	0.86	0.88
PR status	0.86	0.90	0.88
Her2 neu status	0.88	0.84	0.86

AJCC = American Joint Committee on Cancer; ER = estrogen receptor; PR = progesterone receptor.

Table 3

Adjusted probabilities of receiving reconstruction based on patient characteristics.

Variable	Categories	BCS, %	Mastectomy, %	Mast + Recon, %	Adjusted <i>P</i> value
Age	<50	61.80	21.30	16.90	<0.0001
	50–65	67.40	23.30	9.40	
	>65	58.60	39.70	1.60	
Race	Caucasian	65.30	28.80	5.90	0.31
	Black/AA	60.60	33.30	6.10	
	Other	61.60	33.50	4.90	
	Quartile 1	62.20	33.60	4.30	0.19
	Quartile 2	64.10	29.80	6.10	
	Quartile 3	64.10	29.20	6.80	
	Quartile 4	67.50	24.50	8.00	
Educational level	0	65.20	29.10	5.60	0.91
	1	64.20	29.70	6.10	
Total bed size	0–149	78.50	20.40	1.10	0.0009
	150–245	66.90	25.30	7.70	
	>245	55.00	37.70	7.20	
Ambulatory surgery	Hospital	71.50	22.20	6.20	0.02
	network/system	56.10	37.60	6.30	
	No	63.30	31.20	5.60	
RUCA code	Metro	65.10	28.70	6.20	0.005
	Nonmetro	62.60	34.20	3.30	
Tumor stage	T1	72.00	23.20	4.80	<0.0001
	T2	44.10	49.60	6.60	
	T3	34.90	62.60	2.50	
	T4	38.80	58.50	2.70	
Nodal stage	N0	71.00	24.80	4.30	<0.0001
	N1	64.80	30.50	4.70	
	N2	30.10	67.70	2.20	

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Variable	Categories	BCS, %	Mastectomy, %	Mast + Recon, %	Adjusted <i>P</i> value
Estrogen receptor	N3	30.80	66.00	3.20	
	Positive	66.60	29.70	3.70	0.0003
	Negative	55.70	39.50	4.90	
Progesterone receptor	Positive	65.80	30.60	3.70	0.0012
	Negative	55.60	40.00	4.40	
Her2 neu	Positive	54.40	40.10	5.50	0.0015
	Negative	66.00	30.10	3.90	

The adjusted probabilities are presented for each of the a priori patient and institution level predictors identified. These results adjust for the other significant predictors.

Results for T stage, N stage, ER, PR, and Her2 neu status are adjusted for age, race, census median income, census education level. Plastic surgeons per 100,000 female population and radiation oncology services available.

Table 4

Adjusted probabilities of receiving each based on access to specialty care.

Variable	Categories	BCS, %	Mastectomy, %	Mast + recon, %	Adjusted <i>P</i> value
Plastic surgeons per 100,000 female population	4	65.2	27.6	7.2	0.02
	<4	63.4	33.0	3.6	
Number of plastic surgeons per 100 annual breast procedures	0–2	64.4	32.0	3.7	0.19
	2–6	63.7	28.1	8.2	
	>6	64.2	30.1	5.7	
Radiation oncology services available	Hospital/system	66.3	26.9	6.7	0.04
	Venture/none	61.9	33.5	4.6	
Radiation oncologists per 100,000 female population	4	64.0	31.0	5.0	0.55
	<4	64.2	29.1	6.7	
Mean distance to nearest radiation	<5 miles	73.9	22.4	3.7	0.58
	5–10 miles	62.5	29.8	7.7	
	10–20 miles	64.2	29.7	6.1	
	20 miles or more	64.8	31.0	4.2	

A separate model was constructed for each of the primary predictors which adjusted for the significant variables depicted in Table 2. Each probability adjusts for the other significant predictors relative to the categorical outcome variable.

Plastic surgeons per 100,000 female population and radiation oncology services available were in the model together adjusted for patient characteristics (age, race, census median income, and census education level) and hospital characteristics (total bed size, ambulatory surgery, and RUCA code).