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Role of Pre-operative Magnetic Resonance Imaging in the Surgical Management of Early Stage Breast Cancer

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Abstract

Purpose—To examine the role of pre-operative magnetic resonance imaging (pMRI) on time to surgery and rates of re-operation and contralateral prophylactic mastectomy (CPM) using a population-based study of New Jersey breast cancer (BC) patients.

Methods—The study included 289 African-American and 320 white women who participated in the Breast Cancer Treatment Disparity Study and underwent breast surgery for newly diagnosed early stage BC between 2005 and 2010. Patients were identified through rapid case ascertainment by the New Jersey State Cancer Registry. Association between pMRI and time to surgery was examined using linear regression, and with re-operation and CPM using binomial regression.

Results—Half (49.9%) of the study population received pMRI, with higher use for whites compared to African-Americans (62.5% versus 37.5%). After adjusting for potential confounders, patients with pMRI than those without, experienced significantly longer time to initial surgery (geometric mean= 38.7 days; 95% confidence interval: 34.8, 43.0 versus 26.5 days; 95% confidence interval: 24.3, 29.0), significantly higher rate of CPM (relative risk [RR]= 1.82; 95% confidence interval: 1.06, 3.12), and non-significant lower rate of re-operation (RR= 0.76; 95% confidence interval [CI]: 0.54, 1.08).

Conclusions—pMRI was associated with significantly increased time to surgery and higher rate of CPM, but it did not affect the rate of re-operation. Physicians and patients should consider these findings when making surgical decisions based on pMRI findings.

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INTRODUCTION

Current guidelines recommend bilateral mammography as the primary modality and if necessary, ultrasonography to determine tumor extent pre-operatively and plan surgical treatment of early stage breast cancer (BC).[1] There are no recommendations supporting the routine use of pre-operative magnetic resonance imaging (pMRI) in surgical planning of BC due to lack of data showing survival advantage associated with its use. In addition, the few studies that examined the impact of pMRI on BC recurrence have failed to show any benefits.[2–4] Despite the lack of proven benefits on patient outcomes, use of pMRI has increased significantly in the past decade.[5–8]

The growing popularity of pMRI has been based on the assumption that its increased detection capability will result in wider excision and removal of additional disease and therefore, will improve immediate surgical outcomes.[9] Research evaluating pMRI mostly includes single institution studies on re-operation where majority have found no improvement related to pMRI.[3,4,10–16] There are also concerns that pMRI may be associated with recent increases in contralateral prophylactic mastectomy (CPM), and procedures required to evaluate the findings of pMRI may result in unnecessary increases in time to surgery.[5,7,8,17,18] The limited number of studies that have examined the role of pMRI on CPM rates and time to surgery either reported conflicting findings or were unable to adjust for important confounders.[7,8,18–21] The available evidence is therefore insufficient to determine whether pMRI should be included in the routine work-up of BC patients. We conducted a population-based study to investigate the role of pMRI on time to surgery as well rates of re-operation and CPM among early stage BC patients.

METHODS

Study Population and Data Collection

The study population was selected from patients included in the Breast Cancer Treatment Disparity Study (BCTDS). The BCTDS is composed of African-American (AA) and white women who participated in the Women's Circle of Health Study (WCHS), diagnosed with stage I, II, and $T_3N_1M_0$ BC between 2005–2010, with no prior history of cancer other than non-melanoma skin cancer, and age ≤ 85 years. The WCHS is a multi-site case-control study in New York City and New Jersey (NJ) designed to evaluate risk factors for early and aggressive BC in AA and white women.[22,23] The BCTDS cohort included NJ cases from the WCHS who were identified from all major hospitals in seven counties, including Bergen, Essex, Hudson, Mercer, Middlesex, Passaic, and Union through rapid case ascertainment by the NJ State Cancer Registry staff. A total of 634 patients comprised the BCTDS population. Written informed consents were obtained from all patients who agreed to participate and the study was approved by institutional review board at all participating institutions.

All BCTDS patients were included in the current study, except for those who did not undergo breast excision following diagnosis (n=25) resulting in a total of 609 patients. Patients included in the study consented to release of their medical records and provided contact information of health care providers involved in their BC care. These providers were contacted to obtain medical records for abstracting information on socio-demographics,

family history, cancer suspicion, pre-operative and diagnostic investigations, tumor pathology results, and surgical and adjuvant treatment(s). Data was also collected on date of cancer suspicion as well as dates of administration for various tests, procedures, and adjuvant treatments. Abstractors were blinded to study hypothesis and they participated in a standardized training to ensure uniformity of information ascertainment, check for completeness, and prevent systematic differences in data collection between abstractors.

Pre-operative MRI

In all cases, breast cancer was pathologically confirmed either by percutaneous or surgical biopsy. Consequently, first breast excision performed after pathologic diagnosis was defined as initial surgery and consisted of either breast conserving surgery (BCS) or mastectomy. A patient who received MRI any time between the date of cancer suspicion and the date of initial surgery was classified as pMRI recipient. Patients who did not receive MRI in this time period were categorized into the no pMRI group.

Outcomes

Time to surgery was calculated as interval in days from pathologic diagnosis to initial surgery. Subjects who received neo-adjuvant chemotherapy were further excluded from analysis of time to surgery (n= 33). Re-operation was defined as at least one repeat operation performed after initial surgery. It consisted of either re-excision following initial BCS or initial mastectomy, or mastectomy following initial BCS. CPM was defined as removal of the unaffected breast along with affected breast.

Additional Variables

We examined socio-demographics and clinical characteristics including, age at diagnosis, race, education, health insurance, body mass index (BMI), family history of BC (first degree, second degree, or none), method of cancer detection (by patient, physician, or screening mammography), receipt of additional investigations (diagnostic mammogram and ultrasound, additional biopsy following diagnosis, and genotype testing done for mutations in *BRCA1* and *BRCA2* genes), and method of diagnosis (percutaneous or surgical biopsy). Tumor characteristics examined were: grade, histology, size, lymph node status, presence of multifocality or multicentricity, and estrogen, progesterone, and human epidermal growth factor 2 receptor statuses. Margin status at initial surgery was classified into positive, close (≤ 1 mm), and negative. Treatment information including type of initial surgery, surgical facility (teaching or community), and receipt of adjuvant chemotherapy and hormonal therapy was also obtained.

Statistical Analysis

Socio-demographic, clinical characteristics, tumor pathology, and treatment(s) status of the study population were tabulated by receipt of pMRI. Time to surgery, and rates of re-operation and CPM were compared between the two pMRI groups as well by various subject characteristics. Time to surgery (days) was log transformed due to its positively skewed distribution and regression diagnostics were utilized to check for influential observations. Four outliers were identified that were further excluded from analysis of time

to surgery (final n= 572). Linear regression through general linear model was used to estimate unadjusted and adjusted geometric mean with 95% confidence interval (CI) for time to surgery. Geometric means were obtained by exponentiation of parameter estimates from linear regression. Re-operation and CPM rates were examined for all 609 patients in the study. They were reported as percentages, and chi-square test was used to compare rates. Univariate and multivariate binomial regression models were utilized to examine the association between pMRI, and re-operation and CPM. The binomial associations were expressed as relative risk (RR) and 95% CI using nonlinear programming. The variables included in the multivariate models were selected based on prior knowledge as well the association of the variable with both pMRI and study outcomes while keeping a parsimonious approach in mind. The adjusted model for time to surgery included age, race, education, insurance, and type of initial surgery. The multivariate model for re-operation was adjusted for age, race, education, insurance, BMI, method of diagnosis, histology, multifocality or multicentricity, and surgical facility. The multivariate model for CPM was adjusted for age, race, education, insurance, BMI, family history, genotype testing, clinical presentation, multifocality or multicentricity, and surgical facility. Associations with p-values less than 0.05 were considered statistically significant. We also explored findings from additional biopsy that patients received after their pathologic diagnosis by receipt of pMRI. All analyses were conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC).

RESULTS

Of the total 609 BC patients included in the study, 49.9% (304/609) received pMRI. As shown in Table 1, patients receiving pMRI compared to those without, were more likely to be younger, of white race, with higher education, covered by private health insurance, and of normal weight. They were also more likely to have family history of BC, self-discover their BC, undergo diagnostic ultrasound and genotype testing, receive additional biopsies, and get diagnosed by percutaneous biopsy. While examining tumor and treatment characteristics (Table 2), patients who received pMRI more commonly had positive lymph nodes and multifocal or multicentric cancer. However, no differences were seen in tumor grade, histology, and size, surgical margins, receptor status, receipt of adjuvant treatment, and surgical facility.

Study outcomes by receipt of pMRI are shown in Table 3. Geometric mean days to initial surgery was 35.0 (95% CI: 32.6, 37.7) for patients with pMRI and 25.9 (95% CI: 24.1, 27.8) for patients without pMRI ($p<0.001$). Overall, rate of re-operation was 19.2% (117/609) and rate of CPM was 10.7% (65/609). No difference in rate of re-operation was observed between patients with and without pMRI (18.1% and 20.3%, respectively; $p=0.484$). A significantly higher rate of CPM was observed for patients with pMRI than for those without (16.1% and 5.2%, respectively; $p<0.001$).

Distribution of study outcomes by different patient characteristics are presented in Table 4. Time to initial surgery was significantly longer for AAs and for mastectomy patients. Higher re-operation rates were seen for higher BMI, diagnosis by percutaneous biopsy, positive or close margins on initial surgery, and receipt of surgery in community hospital. On the other hand, rates of CPM were higher among those with younger age, white race, private health

insurance, lower BMI, family history of BC, self-recognized cancer, receipt of genotype test, and presence of multifocal or multicentric tumor.

Table 5 presents unadjusted and adjusted association between pMRI and study outcomes. Results from adjusted linear regression showed that patients who received pMRI experienced significantly longer time from diagnosis to initial surgery (geometric mean= 38.7 days; 95% CI: 34.8, 43.0) as compared to patients who did not (geometric mean= 26.5 days; 95% CI: 24.3, 29.0). Receipt of pMRI was not associated with significant reduction in re-operation rate, both in the unadjusted (RR= 0.89; 95% CI: 0.64, 1.23) and adjusted (RR= 0.76; 95% CI: 0.54, 1.08) models. In the unadjusted model, risk of undergoing CPM was more than three times higher for patients who received pMRI compared to those without (RR = 3.07; 95% CI: 1.79, 5.28). After adjusting for potential confounders including age, race, education, insurance, BMI, family history, genotype testing, clinical presentation, multifocality or multicentricity, and surgical facility, receipt of pMRI was associated with RR= 1.82 (95% CI: 1.06, 3.12) of undergoing CPM.

The exploratory analysis showed that 10.2% (31/304) and 4.6% (14/305) patients with and without pMRI respectively, received additional biopsy following the pathological diagnosis. These additional biopsies resulted in positive findings (including additional foci of invasive or in-situ carcinoma) among 16/31 (51.6%) patients with pMRI and 8/14 (57.1%) patients without pMRI, $p>0.05$.

DISCUSSION

Use of pMRI has gained worldwide popularity in surgical planning of BC due to its proven superior accuracy in detecting additional disease compared to conventional imaging. Due to steep rise in pMRI use in the absence of improved patient outcomes, it becomes clinically meaningful to understand its impact on short-term surgical outcomes. In this study we examined the association of pMRI with time to surgery, re-operation, and CPM among early stage BC patients. Approximately half of the study population received pMRI, and 18.8% and 10.7% underwent re-operation and CPM, respectively. Patients receiving pMRI experienced significantly longer time to initial surgery and 1.82 times risk of undergoing CPM; but no difference in re-operation rate as compared to those who did not receive pMRI.

Only two US based studies to date have examined the impact of pMRI on time to surgical treatment. Bleicher et al reported mean times of 57 and 38 days (p=0.01), and Hulvat et al reported median times of 43 and 32 days (p=0.054) in pMRI and no pMRI groups, respectively.[18,21] But these studies reported unadjusted results which can lead to biased estimates due to a large impact of patient characteristics like socioeconomic status, access to care, and race as well as tumor characteristics on treatment delay. This was true for our study population as well, as longer time to surgery was observed for AAs and for those undergoing mastectomy. After adjusting for differences related to age, race, education, insurance, and type of initial surgery, we found that pMRI subjects experienced a significantly longer time to initial surgery (38.9 days versus 27.5 days). The longer delay seen for pMRI group can be explained by additional tests and biopsies that are conducted to investigate MRI findings. The difference seen between the two groups may not have a

detrimental effect on treatment outcome, but longer time taken to initiate surgery may result in increased patient anxiety and treatment dissatisfaction.[21]

In large part, single institution studies have examined differences in re-excision rates by receipt of pMRI. The majority of these reports showed no differences[3,10,11,13,15,16], except for one by Mann et al where a significantly lower rate of re-excision at 5% was seen for patients who received pMRI in comparison to 15% for those who did not.[12] Two recent European randomized trials evaluated the efficacy of pMRI among BC patients. One of them reported no association between pMRI and re-excisions within 6 months of randomization (odds ratio= 0.96; 95% CI: 0.75 to 1.24).[4] The second trial on the other hand, found significant increase in re-excisions after BCS in the pMRI group (34%) versus the control group (12%).[14] Rate of re-operation seen in our study is similar to these pre-existing reports and concurs with most of the available evidence that there is no benefit associated with pMRI on re-operation.

There has been a significant increasing trend in CPM rates nationwide[24,25] even though it provides minimal or no survival benefits.[26,27] CPM is particularly recommended for patients who are at high risk of developing bilateral BC;[28–32] however, majority of women who choose to undergo CPM are not at high risk.[7,19,33,34] A combination of both patient and clinical factors has been associated with its increased use. Few studies have examined pMRI as a predictor of CPM and reported different conclusions.[7,8,19,20] Sorbero et al and King et al showed significantly increased risk of CPM associated with pMRI;[7,8] whereas, two studies did not find any association.[19,20] Additionally, many of them were limited in their ability to control for important confounders. For example almost all of them did not have information on socio-economic variables like education and insurance and some were unable to adjust important clinical variables as well. Results from our analysis also show that pMRI was associated with high risk of CPM, although, the RR declined considerably after adjusting for several relevant socio-demographic and clinical predictors (unadjusted RR= 3.07 versus adjusted RR= 1.82). In our study, patients receiving CPM compared to those who did not, were selectively very different. CPM patients were more likely to be younger, whites, of higher socioeconomic status, privately insured, with family history of BC and therefore, comprised a group of more health conscious patients. It is possible that these patients may proactively ask for pMRI and/or the treating oncologist may prefer to do more extensive work-ups on these patients. As a result, after adjusting for these factors the RR was minimized, but it was not eliminated completely; hence suggesting that pMRI is one of the independent predictors that may influence patients' decision to opt for CPM.

A longer delay or excess of surgeries observed for pMRI group can be considered useful if, in fact, it increases the chances of identifying additional cancer as compared to no pMRI group. In our study, although the pMRI group was twice more likely to receive additional biopsy, no difference was seen in proportions with positive findings on biopsies by receipt of pMRI.

Our study had some potential limitations. We were unable to evaluate that whether the decision to undergo CPM was based on findings of pMRI or not. We also did not have data on other additional tests that may have been performed to investigate pMRI findings and

their influence on surgical outcomes. The study however, utilizes the strength of detailed clinical information available in medical records such that confounding by indication is not a major issue. Additionally, this is a population-based study including many hospitals in a diverse area which provides increased generalizability about impact of pMRI on surgical outcomes in contrast to most of the existing reports that are single institution based.

In conclusion, we found that pMRI did not offer any substantial benefits in surgical management of BC patients. The re-operation rates did not differ significantly by receipt of pMRI. Additionally, pMRI had a significant influence on receipt of CPM and in increasing time to surgery. We recommend that patients should be counseled about the lack of benefits of pMRI during surgical decision making.

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Synopsis

This study examined the impact of pre-operative MRI on surgical management of early stage breast cancer patients. While pre-operative MRI did not impact re-operation rates, it significantly increased time to surgery and rate of contralateral prophylactic mastectomy.

Table 1

Socio-demographic and clinical characteristics of the study population, by receipt of pMRI

Characteristics, n (%)	pMRI received (n= 304)	pMRI not received (n= 305)	*P-value*
Age at diagnosis, years			*<0.001*
< 45	67 (22.0)	52 (17.0)	
45–54	109 (35.9)	75 (24.6)	
55–64	92 (30.3)	109 (35.7)	
≥ 65	36 (11.8)	69 (22.6)	
Race			*<0.001*
White	190 (62.5)	130 (42.6)	
African-American	114 (37.5)	175 (57.4)	
Education			*<0.001*
Below college	124 (40.8)	182 (59.7)	
≥College graduate	139 (45.7)	91 (29.8)	
Unknown	41 (13.5)	32 (10.5)	
Health insurance			*<0.001*
Non-private*	49 (16.1)	105 (34.4)	
Private	236 (77.6)	185 (60.7)	
Unknown	19 (6.3)	15 (4.9)	
Body mass index, kg/m^2			*0.009*
≤24.9	117 (38.5)	84 (27.5)	
25.0 – 29.9	87 (28.6)	83 (27.2)	
≥30.0	97 (31.9)	134 (43.9)	
Unknown	3 (1.0)	4 (1.3)	
Family history of breast cancer			*0.195*
First degree relative	78 (25.7)	63 (20.7)	
Second degree relative	58 (19.1)	52 (17.0)	
None	168 (55.3)	190 (62.3)	
Clinical presentation			*0.024*
Patient finding	141 (46.4)	114 (37.4)	
Physician finding or screening mammography	163 (53.6)	191 (62.6)	
Additional investigations			
Diagnostic mammogram	289 (95.1)	292 (95.7)	*0.692*
Diagnostic ultrasonography	258 (84.9)	228 (74.8)	*0.002*
Genotype testing	72 (23.7)	33 (10.8)	*<0.001*
Additional biopsies	31 (10.2)	14 (4.6)	*<0.001*
Method of diagnosis			*<0.001*
Percutaneous biopsy	269 (88.5)	231 (75.7)	
Surgical biopsy	35 (11.5)	74 (24.3)	

Abbreviations: pMRI= pre-operative magnetic resonance imaging.

*Non-private insurance includes Medicare, Medicaid, no insurance, and charity care.

P-values were derived from chi-square test for proportions.

Table 2

Tumor and treatment characteristics of the study population, by receipt of pMRI

Tumor characteristics, n (%)	pMRI received (n= 304)	pMRI not received (n= 305)	*P-value*
Tumor grade			*0.660*
Well differentiated	61 (20.1)	53 (17.4)	
Moderately differentiated	119 (39.1)	130 (42.6)	
Poorly differentiated	107 (35.2)	109 (35.7)	
Unknown	17 (5.6)	13 (4.3)	
Tumor histology			*0.345*
Invasive lobular	35 (11.5)	28 (9.2)	
Other invasive	269 (88.5)	277 (90.8)	
Tumor size			*0.326*
≤ 1.0cm	104 (34.2)	116 (38.0)	
> 1.0cm	200 (65.8)	189 (62.0)	
Lymph node status			*0.002*
Negative	206 (67.8)	238 (78.0)	
Positive	97 (31.9)	62 (20.3)	
Unknown	1 (0.3)	5 (1.6)	
Multifocal or Multicentric tumor			*0.042*
Yes	72 (23.7)	52 (17.0)	
No	232 (76.3)	253 (83.0)	
Margin status at initial surgery			*0.478*
Positive	38 (12.5)	41 (13.4)	
Close	47 (15.5)	37 (12.1)	
Negative	218 (71.7)	227 (74.4)	
Unknown	1 (0.3)	0 (0.0)	
Receptor Status			
ER positive	239 (78.6)	235 (77.0)	*0.896*
PR positive	214 (70.4)	194 (63.6)	*0.189*
HER2 positive	50 (16.4)	53 (17.4)	*0.954*
Triple negative	37 (12.2)	51 (16.7)	*0.277*
Initial surgery			*0.194*
Breast conserving surgery	188 (61.8)	204 (66.9)	
Mastectomy	116 (38.2)	101 (33.1)	
Adjuvant therapy			*0.129*
Chemotherapy only	66 (21.7)	63 (20.7)	
Hormonal therapy only	105 (34.5)	125 (41.0)	
Chemotherapy and hormonal therapy	119 (39.1)	96 (31.5)	
None	14 (4.6)	21 (6.9)	
Type of surgical facility			*0.651*
Teaching-based	171 (56.3)	166 (54.4)	
Community-based	133 (43.8)	139 (45.6)	

Abbreviations: pMRI= pre-operative magnetic resonance imaging; ER= estrogen receptor; PR= progesterone receptor; HER2= human epidermal growth factor receptor 2.

P-values were derived from chi-square test for proportions.

Table 3

Time to surgery and Rate of Re-operation and CPM, by receipt of pMRI

Outcomes	pMRI received	pMRI not received	*P-value*
Time to surgery, days	n= 281	n= 291	
Geometric mean (95% CI)	35.0 (32.6, 37.7)	25.9 (24.1, 27.8)	*<0.001*
Re-operation, n (%)	n= 304	n= 305	
Yes	55 (18.1)	62 (20.3)	*0.484*
No	249 (81.9)	243 (79.7)	
CPM, n (%)	n= 304	n= 305	
Yes	49 (16.1)	16 (5.2)	*<0.001*
No	255 (83.9)	289 (94.8)	

Abbreviations: pMRI= pre-operative magnetic resonance imaging; CI= confidence interval; CPM= contralateral prophylactic mastectomy.

P-values were derived from general linear model for means and chi-square test for proportions.

Table 4

Time to surgery and Rate of Re-operation and CPM, by subject characteristics

Characteristics	Time to surgery, geometric mean days (95% CI) n= 572	Re-operation rate, % n= 609	CPM rate, % n= 609
Age at diagnosis, years			
< 45	30.4 (26.9, 34.3)	19.3	25.2
45–54	30.8 (28.0, 33.8)	18.5	13.6
55–64	29.2 (26.7, 32.0)	21.9	4.5
≥ 65	30.1 (26.6, 34.1)	15.2	1.0
	p= 0.877	*p= 0.560*	*p< 0.001*
Race			
White	28.0 (26.0, 30.0)	17.8	15.9
African-American	32.6 (30.2, 35.1)	20.8	4.8
	p= 0.004	*p= 0.356*	*p< 0.001*
Education			
Below college	29.7 (27.6, 32.0)	19.9	8.5
≥ College graduate	29.1 (26.8, 31.7)	20.4	13.9
Unknown	34.7 (29.9, 40.3)	12.3	9.6
	p= 0.125	*p=0.279*	*p= 0.126*
Health insurance			
Non-private	32.5 (29.3, 36.1)	16.9	2.6
Private	29.0 (27.2, 30.9)	19.5	13.8
Unknown	32.7 (26.3, 40.6)	26.5	8.8
	p= 0.126	*p= 0.425*	*p< 0.001*
Body mass index, kg/m^2			
≤ 24.9	29.0 (26.5, 31.8)	11.9	20.4
25.0 – 29.9	30.4 (27.6, 33.6)	20.6	7.6
≥ 30.0	30.7 (28.2, 33.4)	25.1	4.8
	p= 0.816	*p= 0.003*	*p< 0.001*
Family history			
First degree relative	31.1 (27.9, 34.6)	17.0	13.5
Second degree relative	31.2 (27.6, 35.2)	20.0	17.3
None	29.3 (27.3, 31.4)	19.8	7.5
	p= 0.525	*p= 0.753*	*p= 0.007*
Clinical presentation			
Patient finding	29.2 (26.9, 31.7)	15.7	14.9
Physician finding or screening mammography	30.6 (28.6, 32.7)	21.8	7.6
	p= 0.387	*p= 0.061*	*p= 0.004*
Genotype testing			
Done	33.3 (29.4, 37.8)	18.1	35.2
Not done	29.4 (27.8, 31.1)	19.4	5.6

Characteristics	Time to surgery, geometric mean days (95% CI) n= 572	Re-operation rate, % n= 609	CPM rate, % n= 609
	p= 0.076	*p= 0.750*	*p< 0.001*
Method of diagnosis			
Percutaneous biopsy	30.8 (29.0, 32.6)	21.4	10.8
Surgical biopsy	27.1 (24.0, 30.6)	9.2	10.1
	p= 0.064	*p= 0.003*	*p= 0.828*
Tumor grade			
Well differentiated	31.3 (27.9, 35.2)	20.2	7.9
Moderately differentiated	29.4 (27.1, 31.9)	16.9	11.2
Poorly differentiated	30.0 (27.4, 32.8)	20.8	11.6
Unknown	30.9 (24.5, 39.0)	23.3	10.0
	p= 0.835	*p= 0.649*	*p= 0.751*
Tumor histology			
Invasive lobular	26.7 (22.7, 31.4)	17.5	11.1
Other Invasive	30.5 (28.8, 32.2)	19.4	10.6
	p= 0.128	*p= 0.709*	*p= 0.905*
Tumor size			
≤ 1.0cm	31.4 (28.9, 34.2)	21.4	10.5
> 1.0cm	29.2 (27.4, 31.3)	18.0	10.8
	p= 0.193	*p= 0.311*	*p= 0.895*
Lymph node status			
Negative	30.2 (28.4, 32.0)	19.1	9.5
Positive	29.7 (26.7, 33.1)	20.1	14.5
Unknown	29.9 (18.0, 49.9)	0.0	0.0
	p= 0.976	*p= 0.469*	*p= 0.150*
Multifocal or Multicentric tumor			
Yes	----	25.0	17.7
No	----	17.7	8.9
		p= 0.067	*p= 0.004*
Margin status at initial surgery			
Positive	----	81.0	----
Close	----	40.5	----
Negative	----	4.0	----
		p< 0.001	
Initial surgery			
Mastectomy	36.5 (33.4, 39.9)	----	----
Lumpectomy	27.3 (25.6, 29.0)	----	----
	p< 0.001		
Type of surgical facility			
Teaching-based	31.2 (29.1, 33.5)	15.4	12.5
Community-based	28.7 (26.6, 31.0)	23.9	8.5

Characteristics	Time to surgery, geometric mean days (95% CI)	Re-operation rate, %	CPM rate, %
	n= 572	n= 609	n= 609
	p= 0.117	*p= 0.008*	*p= 0.111*

Abbreviations: CI= confidence interval; CPM= contralateral prophylactic mastectomy.

P-values were derived from general linear model for means and chi-square test for proportions.

Table 5

Unadjusted and adjusted association between pMRI and study outcomes

Outcomes	pMRI	Unadjusted geometric mean (95% CI)	Adjusted geometric mean (95% CI)¶
Time to surgery, days	Yes	35.0 (32.6, 37.7)	38.9 (34.5, 41.6)
	No	25.9 (24.1, 27.8)	27.5 (25.2, 30.0)
		Unadjusted RR (95% CI)	Adjusted RR (95% CI)
Re-operation	Yes	0.89 (0.64, 1.23)	0.76 (0.54, 1.08)†
	No	Ref	Ref
CPM	Yes	3.07 (1.79, 5.28)	1.82 (1.06, 3.12)‡
	No	Ref	Ref

Abbreviations: pMRI= pre-operative magnetic resonance imaging; CI= confidence interval; RR= relative risk; CPM= contralateral prophylactic mastectomy.

¶Adjusted for age, race, education, insurance, and type of initial surgery.

†Adjusted for age, race, education, insurance, body mass index, method of diagnosis, histology, multifocality/multicentricity and surgical facility.

‡Adjusted for age, race, education, insurance, body mass index, family history of breast cancer, genotype testing, clinical presentation, multifocality/multicentricity, and surgical facility.