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The Role of Preoperative Magnetic Resonance Imaging (MRI) in the Workup and Surgical Treatment of Interval and Screen-Detected Breast Cancer in Older Women

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Abstract

Goals—We describe the relationship between preoperative Magnetic Resonance Imaging (MRI) and the utilization of additional imaging, biopsy, and primary surgical treatment for subgroups of women with interval versus screen-detected breast cancer. We determined the proportion of women receiving additional breast imaging or biopsy and type of primary surgical treatment, stratified by use of preoperative MRI, separately for both groups.

Methods—Using Breast Cancer Surveillance Consortium (BCSC) data, we identified a cohort of women age 66 and older with an interval or screen-detected breast cancer diagnosis between 2005–2010. Using logistic regression, we explored associations between primary surgical treatment type and preoperative MRI use for interval and screen-detected cancers.

Results—There were 204 women with an interval cancer and 1254 with a screen-detected cancer. The interval cancer group was more likely to receive preoperative MRI (21% vs. 13%). In both groups, women receiving MRI were more likely to receive additional imaging and/or biopsy. Receipt of MRI was not associated with increased odds of mastectomy (OR =0.99, 95% CI: 0.67–1.50), while interval cancer diagnosis was associated with significantly higher odds of mastectomy (OR=1.64, 95% CI: 1.11–2.42).

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Conclusion—Older women with interval cancer were more likely than women with a screen-detected cancer to have preoperative MRI, however, those with an interval cancer had 64% higher odds of mastectomy regardless of receipt of MRI. Given women with interval cancer are reported to have a worse prognosis, more research is needed to understand effectiveness of imaging modalities and treatment consequences within this group.

Keywords

Breast cancer; preoperative MRI; breast surgery; interval breast cancer

Introduction

Preoperative MRI refers to the use of MRI as part of a clinical evaluation following a breast cancer diagnosis and before primary surgery. It is used to determine the extent of disease and to detect additional disease not detected at initial presentation in women with a newly diagnosed breast cancer (1). Preoperative MRI usage has increased from 10% in 2003 to 27–40% in 2007 (1). Multiple clinical trials and a meta-analysis have shown that breast MRI detects otherwise occult cancer in an average of 16% of women in the ipsilateral breast (2) and 3–10% in the contralateral breast (3–6). Evidence shows that preoperative MRI detected contralateral breast cancers in 6% of women with an infiltrating lobular carcinoma, 3.4 % with invasive cancer, and 3% with ductal carcinoma in situ (DCIS) (6). Studies comparing the effectiveness of preoperative breast MRI to mammography and/or ultrasound for both work-up and outcomes have found that with the detection of additional disease comes additional work-up and possibly more extensive surgery (7–10). While recent studies have begun to investigate the surgical management and clinical outcomes associated with preoperative MRI, such as mastectomy rates, local recurrence and survival, the initial reports are conflicting (1), with several recent studies reporting no benefit (11–13) (1). This controversy around the benefits of preoperative MRI (14) (10) (15) (1) continues, and research and assessment among patient subgroups is emerging (16–18) (8).

One important subgroup not currently investigated in the preoperative MRI literature is women with an interval breast cancer diagnosis. Interval breast cancers are those diagnosed after a negative screening mammogram and before the next routine screening examination. Approximately 10%–20% of breast cancers are not routinely detected during a mammography screening (19, 20). Interval cancers have been shown to have a poorer prognosis than screen-detected cancers, with a higher proportion being invasive lobular, more advanced in stage, less differentiated, triple-negative, and having lower 5-year survival (21–23). Therefore, understanding the utilization of advanced imaging, additional biopsy, and primary surgical treatment for women with an interval versus screen-detected cancer is important to inform comparative effectiveness studies on the clinical utility of preoperative breast MRI.

The purpose of our study was to better understand and describe the relationship between preoperative MRI and utilization of additional imaging, biopsy, and surgical outcomes for subgroups of women with interval or screen-detected breast cancer. We hypothesized that in women with a diagnosis of interval breast cancer, preoperative MRI would be more strongly

associated with use of additional imaging, biopsy and mastectomy versus women with a screen-detected breast cancer. Therefore, we examined 1) the relationships between preoperative MRI use and receipt of additional imaging and/or biopsy for women with interval cancer versus screen-detected diagnoses and 2) the relationships between preoperative MRI use and primary surgical treatment (mastectomy or breast conserving surgery) for women with interval and screen-detected cancer diagnoses.

Materials and Methods

Data Sources

Data for this study was obtained from the Breast Cancer Surveillance Consortium (BCSC) Data Resource. More information regarding this resource is available at: http://breastscreening.cancer.gov/. The study population included women from the Breast Cancer Surveillance Consortium (BCSC) whose registry records have been linked to Medicare claims. The BCSC is a national collaboration of breast cancer screening registries that has been funded by the National Cancer Institute since 1996 (24). Data were obtained from four BCSC registries -Carolina Mammography Registry, New Hampshire Mammography Network, San Francisco Mammography Registry, and Vermont Breast Cancer Surveillance System - that participated in linkage of BCSC records and Medicare Claims data. Information collected by the BCSC includes breast cancer radiology examination information (e.g. indication for examination, mammography interpretation using Breast Imaging Report and Data System - (BIRADS®) (25), recommended follow-up after imaging, and breast density) linked to information from state cancer registries (24).

We used beneficiary and billing data collected by the Centers for Medicare and Medicaid Services (CMS) for inpatient (MedPAR), hospital outpatient (Outpatient), and physician services (Carrier). Billing data provided information on procedures based on International Classification of Disease, Version 9 (ICD-9), Current Procedure Terminology (CPT), and Healthcare Common Procedure Coding System (HCPCS) codes. In addition, the Medicare enrollment file maintains data on demographic factors, vital status, enrollment and eligibility status for Medicare benefits. Data were pooled at a central Statistical Coordinating Center (SCC) at Group Health Research Institute (Seattle, WA). The SCC and all BCSC registries received Institutional Review Board approval for active or passive consenting processes or a waiver of consent to enroll participants, link data and conduct analysis. All procedures were Health Insurance Portability and Accountability Act (HIPAA) compliant and all registries and the SCC have received a Federal Certificate of Confidentiality and other protection for the identities of women, physicians, and facilities who are subjects of this research.

Study Population

Among women from the four BCSC registries linked to Medicare claims, the study cohort included those who were 66 years of age or older at the time of a BCSC-captured screening mammogram in 2005–2009 (N=212,953). Among these women, 2,741 had a breast cancer diagnosis within 365 days following a screening mammogram. To ensure complete capture of Medicare claims, we included women who were enrolled in Medicare parts A and B and were not enrolled in a Medicare HMO for one year prior to and six months post breast

cancer diagnosis (N=1,552). Finally, we restricted the cohort to women who had primary breast surgery within 6 months of diagnosis (N=1,458).

Measures and Definitions

The primary predictor, interval versus screen-detected cancer, was defined based on the assessment and recommendations from the BCSC screening mammogram. An interval cancer was defined as a breast cancer diagnosed within 365 days following a negative screening mammogram (BIRADS 1, 2, or 3 without recommendation for immediate evaluation). A screen-detected cancer was defined as a breast cancer diagnosis occurring within 365 days following a positive screening mammogram (BIRADS 0, 4, 5, or 3 with recommendation for immediate evaluation) (26). Women with any MRI in Medicare claims, based on CPT/HCPCS or ICD-9 codes (see Appendix A), found from the breast cancer diagnosis date up to and including the primary surgical treatment date were defined as having a preoperative MRI.

Primary surgical treatment was defined as the first breast cancer surgery within six months of breast cancer diagnosis and was classified as mastectomy or breast conserving surgery based on cancer registry data captured by the BCSC. Medicare claims were used to define any additional breast imaging (mammography or ultrasound) or biopsy (see Appendix A) within a six month window between the breast cancer diagnosis and primary surgical treatment.

Patient characteristics including age at diagnosis, race/ethnicity, education, parity, age at menarche, family history of breast cancer, personal history of breast biopsy, radiologic-reported breast imaging-reporting (BIRADS) breast density, and five-year breast cancer risk (a cutoff of 1.67 for delineating between lower and higher five-year breast cancer risk) (27) were identified using BCSC data. Education, parity, family history of breast cancer, personal history of breast biopsy, breast density, and five-year breast cancer risk, were captured at the time of mammography screening. All cancer characteristics including cancer type (DCIS, invasive lobular, invasive other-including invasive ductal), stage (American Joint Committee on Cancer (AJCC) version 6 - 0, I, II, III, IV), estrogen /progesterone Receptor (ER/PR) status, HER2/neu, size, grade, nodal status, and laterality were identified using BCSC data. Comorbidity score in the year prior to the screening mammogram was derived from Medicare claims files using the Klabunde adaptation to the Charlson comorbidity score (28).

Statistical Analysis

Descriptive statistics were used to describe patient and cancer characteristics overall and by interval/screen-detected cancer diagnosis. We described the proportion of women receiving any additional breast imaging or biopsy and the type of primary surgical treatment in relation to receipt of preoperative MRI separately for interval and screen-detected cancers. Multivariable logistic regression models explored the relationship between interval cancer diagnosis, preoperative MRI use, and their interaction with type of primary surgical treatment.

To account for factors associated with interval cancers, we used models that adjusted for age at diagnosis (ages 66–69, 70–74, 75–79, and 80+), breast density (fatty/scattered or

heterogeneously dense/extremely dense), cancer type (DCIS, invasive lobular, invasive other – including invasive ductal), tumor size, AJCC stage, grade and nodal status. Odds ratios (OR) and 95% confidence intervals (95% CI) of mastectomy vs. breast conserving surgery are reported. Statistical significance was evaluated at the two-sided alpha = 0.05 level. Analyses were conducted using SAS (*SAS 9.3 System Options: Reference, Second Edition*. Cary, NC: SAS Institute Inc.; 2011.).

Results

Our sample included 204 women with an interval cancer diagnosis and 1254 women with a screen-detected cancer diagnosis. The median inter-quartile range (IQR) number of days from screening mammogram to diagnosis for interval cancers was 238 (129–306) and for screen-detected cancers was 23 (13–41). The median (IQR) number of days from diagnosis to primary surgical treatment for interval cancers was 20.5 (11–34.5) and for screen-detected cancer was 23 (11–38). In the study cohort, 205 (14%) had a preoperative MRI and 359 (25%) had a mastectomy.

Patient and cancer characteristics were compared for the interval versus screen-detected groups (Tables I and II). Age was similar between the two groups. Compared to women with screen-detected cancers, women in the interval cancer group were more likely to receive preoperative MRI (21% interval vs. 13% screen-detected); have invasive cancer (25% interval vs. 14% screen-detected); have a higher cancer stage (II, III, IV) (48% interval vs. 21% screen-detected); have larger tumors (≥20 mm, 47% interval vs. 21% screen-detected); a grade of poorly differentiated (33% interval vs. 25% screen-detected); and have one or more positive nodes (22% interval vs. 13% screen-detected).

In both the interval and screen-detected cancer groups, women receiving preoperative MRI were more likely to receive additional imaging with mammography or ultrasound than women without MRI (Table III). Among women with an interval cancer diagnosis, 30% of those receiving preoperative MRI had additional imaging with mammography or ultrasound compared to 22% of women without preoperative MRI. Women receiving MRI were also more likely to receive additional biopsies in both the interval and screen-detected sub-groups.

Women with interval cancers were more likely to have mastectomies compared to women with screen-detected cancer (40% vs. 22%, respectively). However, among women diagnosed with interval cancer, the percentage of women with mastectomies was similar between those receiving and not receiving preoperative MRI (39.5% MRI vs. 40.3% No MRI). Among women with screen-detected cancers, mastectomy was slightly more common in women receiving MRI (26% MRI vs. 22% No MRI; Table III). In an adjusted logistic regression model for primary breast surgery, we found no interaction between interval cancer diagnosis and preoperative MRI (p=0.38). Receipt of preoperative MRI was not associated with odds of mastectomy (OR =0.99, 95% CI: 0.67–1.50) while interval cancer diagnosis was associated with significantly higher odds of mastectomy (OR=1.64, 95% CI: 1.11–2.42).

Discussion

This study is the first to report the relationship between preoperative MRI and additional work-up and primary surgical treatment in sub-groups defined by breast cancer mode of detection (interval versus screen-detected). Previous studies have examined MRI use and outcomes in women with occult disease (29), however these studies have not reported findings for the clinically distinct interval cancer cases. Women with an interval cancer diagnosis were more likely to receive MRI. Although all women receiving MRI were more likely to receive additional imaging and biopsy, we found that a higher proportion of women with an interval cancer had a mastectomy than women with screen-detected cancers, regardless of MRI use (21% vs. 13%). Even after adjusting for patient and cancer characteristics, women with interval cancer were over 60%, more likely to have a mastectomy compared to women with a screen-detected cancer.

Many previous studies have accounted for cancer histology, stage, grade, tumor size and other prognostic cancer characteristics when assessing utilization of imaging, biopsy, and surgical management for breast cancer in relation to preoperative MRI. However, our results indicate that even after adjustment for these key prognostic factors, women with interval cancers were different from those with screen-detected cancers in relation to pre-operative MRI and surgical treatment. Women with an interval cancer were more likely to have a mastectomy regardless of whether or not they had a preoperative MRI, suggesting there may be other factors related to interval cancer that impact surgical management. For example, the anxiety level for a woman with an interval cancer may be higher than a woman with a screen-detected cancer because her cancer was missed on a previous mammogram. Hence, even though these women have more advanced disease and surgical options may be limited, women with interval cancer that do have surgical options may opt for a more extensive surgery to relieve her anxiety about risk of recurrence.

Interval breast cancers represent a challenging subgroup to study, given the relatively small numbers represented in existing population-based data. However, given the poorer prognosis among these women, this subpopulation is important to consider when evaluating the utilization and outcomes of breast imaging modalities such as MRI. Published literature on preoperative MRI has reported the conundrum of a preoperative modality that is optimal for detecting subclinical cancer foci and extent of disease yet with little evidence of benefits in short or long-term outcomes (1, 14). As the effectiveness of preoperative breast MRI is evaluated for benefits and harms, it is important to account for – and perhaps identify – subgroups of women for whom the influence of MRI may be diminished due to factors unique to those groups. This study begins to fill that gap for interval cancers.

This study has the strength of the BCSC data – a national, longitudinal sample with detailed clinical data – linked to Medicare claims. Although the BCSC-Medicare data are novel and rich, they limited our study cohort to women age 66 years and older. Therefore our findings may not be generalizable to younger women. Also, although we were able to explicitly identify interval cancers based on screening information and cancer registry data, we could not distinguish missed interval cancers (not identified by radiologist) from true interval cancers (not detectable on prior screening mammogram). This is a limitation seen in prior

studies (19, 30–32), and is less likely to influence the outcomes of this study, since we accounted for several factors that may relate to missed versus true interval cancers, such as lobular histology and breast density in adjusted analyses. We did not include neo-adjuvant therapy as a primary treatment; however, the median number of days to surgery (20.5 vs. 23 days, respectively) was similar between the interval and screen-detected cancer groups, suggesting use of neo-adjuvant therapy was not more common in one group over the other.

There is no clinical consensus, and no recommendation for women with an interval cancer diagnosis to guide workup or treatment decisions (33). Our study suggests that women with interval cancers are more likely to receive MRI and mastectomy compared to screen-detected cancers. There is little literature on patient and physician surgical treatment decisions following an interval breast cancer diagnosis. If women with interval cancer are more likely to receive mastectomy regardless of preoperative imaging, then the benefit of detecting additional cancer with MRI is not likely to matter. As the evidence base expands to inform patient choices for optimal outcomes, interval cancers patients are an important subgroup to evaluate, given the poorer prognosis for these women.

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References

1. McLaughlin S, Mittendorf EA, Bleicher RJ, McCready DR, King TA. The 2013 Society of Surgical Oncology Susan G Komen for the Cure Symposium: MRI in breast cancer: where are we now? Ann Surg Oncol. 2014; 21(1):28–36. [PubMed: 24145992]
2. Houssami N, Abraham LA, Miglioretti DL, Sickles EA, Kerlikowske K, Buist DS, et al. Accuracy and outcomes of screening mammography in women with a personal history of early-stage breast cancer. JAMA. 2011; 305(8):790–9. [PubMed: 21343578]
3. Veronesi U, Cascinelli N, Mariani L, Greco M, Saccozzi R, Luini A, et al. Twenty-year follow-up of a randomized study comparing breast-conserving surgery with radical mastectomy for early breast cancer. N Engl J Med. 2002; 347(16):1227–32. [PubMed: 12393819]
4. Samant RS, Olivotto IA, Jackson JS, Mates D. Diagnosis of metachronous contralateral breast cancer. Breast J. 2001; 7(6):405–10. [PubMed: 11843852]
5. Poggi MM, Danforth DN, Sciuto LC, Smith SL, Steinberg SM, Liewehr DJ, et al. Eighteen-year results in the treatment of early breast carcinoma with mastectomy versus breast conservation therapy: the National Cancer Institute Randomized Trial. Cancer. 2003; 98(4):697–702. [PubMed: 12910512]
6. Lehman CD, Gatsonis C, Kuhl CK, Hendrick RE, Pisano ED, Hanna L, et al. MRI evaluation of the contralateral breast in women with recently diagnosed breast cancer. N Engl J Med. 2007; 356(13): 1295–303. [PubMed: 17392300]

7. Heil J, Buehler A, Golatta M, Rom J, Schipp A, Harcos A, et al. Do patients with invasive lobular breast cancer benefit in terms of adequate change in surgical therapy from a supplementary preoperative breast MRI? Ann Oncol. 2012; 23(1):98–104. [PubMed: 21460377]
8. Kapoor NS, Eaton A, King TA, Patil S, Stempel M, Morris E, et al. Should breast density influence patient selection for breast-conserving surgery? Ann Surg Oncol. 2013; 20(2):600–6. [PubMed: 22941162]
9. Pengel KE, Loo CE, Wesseling J, Pijnappel RM, Rutgers EJ, Gilhuijs KG. Avoiding preoperative breast MRI when conventional imaging is sufficient to stage patients eligible for breast conserving therapy. Eur J Radiol. 2014; 83(2):273–8. [PubMed: 24220546]
10. Turnbull L, Brown S, Harvey I, Olivier C, Drew P, Napp V, et al. Comparative effectiveness of MRI in breast cancer (COMICE) trial: a randomised controlled trial. Lancet. 2010; 375(9714): 563–71. [PubMed: 20159292]
11. Wang SY, Virnig BA, Tuttle TM, Jacobs DR Jr, Kuntz KM, Kane RL. Variability of preoperative breast MRI utilization among older women with newly diagnosed early-stage breast cancer. Breast J. 2013; 19(6):627–36. [PubMed: 24011145]
12. Sommer CA, Stitzenberg KB, Tolleson-Rinehart S, Carpenter WR, Carey TS. Breast MRI utilization in older patients with newly diagnosed breast cancer. J Surg Res. 2011; 170(1):77–83. [PubMed: 21658724]
13. Guilfoyle C, Christoudias M, Collett AE, Gracely EJ, Frazier TG, Barrio AV. Effect of preoperative MRI on mastectomy and contralateral prophylactic mastectomy rates at a community hospital by a single surgeon. Breast J. 2014; 20(1):79–83. [PubMed: 24438066]
14. Bleicher RJ. Breast magnetic resonance imaging as it is, in contrast to how we wish it to be. J Clin Oncol. 2014; 32(5):370–2. [PubMed: 24395864]
15. Bleicher RJ, Ciocca RM, Egleston BL, Sesa L, Evers K, Sigurdson ER, et al. Association of routine pretreatment magnetic resonance imaging with time to surgery, mastectomy rate, and margin status. J Am Coll Surg. 2009; 209(2):180–7. quiz 294–5. [PubMed: 19632594]
16. Bae MS, Moon WK, Cho N, Chang JM, Seo M, Park IA, et al. Patient age and tumor size determine the cancer yield of preoperative bilateral breast MRI in women with ductal carcinoma in situ. AJR Am J Roentgenol. 2013; 201(3):684–91. [PubMed: 23971464]
17. Kim JY, Cho N, Koo HR, Yi A, Kim WH, Lee SH, et al. Unilateral breast cancer: screening of contralateral breast by using preoperative MR imaging reduces incidence of metachronous cancer. Radiology. 2013; 267(1):57–66. [PubMed: 23329656]
18. Petrillo A, Porto A, Fusco R, Filice S, Vallone P, Rubulotta MR, et al. Surgical impact of preoperative breast MRI in women below 40 years of age. Breast Cancer Res Treat. 2013; 140(3): 527–33. [PubMed: 23893089]
19. Gilliland FD, Joste N, Stauber PM, Hunt WC, Rosenberg R, Redlich G, et al. Biologic characteristics of interval and screen-detected breast cancers. J Natl Cancer Inst. 2000; 92(9):743–9. [PubMed: 10793111]
20. Kerlikowske K, Hubbard RA, Miglioretti DL, Geller BM, Yankaskas BC, Lehman CD, et al. Comparative effectiveness of digital versus film-screen mammography in community practice in the United States: a cohort study. Ann Intern Med. 2011; 155(8):493–502. [PubMed: 22007043]
21. Domingo L, Blanch J, Servitja S, Corominas JM, Murta-Nascimento C, Rueda A, et al. Aggressiveness features and outcomes of true interval cancers: comparison between screen-detected and symptom-detected cancers. Eur J Cancer Prev. 2013; 22(1):21–8. [PubMed: 22584215]
22. Hoff SR, Abrahamsen AL, Samset JH, Vigeland E, Klepp O, Hofvind S. Breast cancer: missed interval and screening-detected cancer at full-field digital mammography and screen-film mammography-- results from a retrospective review. Radiology. 2012; 264(2):378–86. [PubMed: 22700555]
23. Poplack SP, Tosteson AN, Grove MR, Wells WA, Carney PA. Mammography in 53,803 women from the New Hampshire mammography network. Radiology. 2000; 217(3):832–40. [PubMed: 11110951]

24. Ballard-Barbash R, Taplin SH, Yankaskas BC, Ernster VL, Rosenberg RD, Carney PA, et al. Breast Cancer Surveillance Consortium: a national mammography screening and outcomes database. AJR Am J Roentgenol. 1997; 169(4):1001–8. [PubMed: 9308451]

25. Balleyguier C, Ayadi S, Van Nguyen K, Vanel D, Dromain C, Sigal R. BIRADS classification in mammography. Eur J Radiol. 2007; 61(2):192–4. [PubMed: 17164080]

26. Breast Cancer Surveillance Consortium. Performance Measures for 1,838,372 Screening Mammography Examinations from 2004 to 2008 by Time (Months) Since Previous Mammography -- based on BCSC data through 2009. http://breastscreening.cancer.gov/data/performance/screening/2009/perf_time.html

27. Tice JA, Cummings SR, Smith-Bindman R, Ichikawa L, Barlow WE, Kerlikowske K. Using clinical factors and mammographic breast density to estimate breast cancer risk: development and validation of a new predictive model. Ann Intern Med. 2008; 148(5):337–47. [PubMed: 18316752]

28. Klabunde CN, Harlan LC, Warren JL. Data sources for measuring comorbidity: a comparison of hospital records and medicare claims for cancer patients. Med Care. 2006; 44(10):921–8. [PubMed: 17001263]

29. Pilewskie M, King TA. Magnetic resonance imaging in patients with newly diagnosed breast cancer: A review of the literature. Cancer. 2014

30. Lehman CD, DeMartini W, Anderson BO, Edge SB. Indications for breast MRI in the patient with newly diagnosed breast cancer. J Natl Compr Canc Netw. 2009; 7(2):193–201. [PubMed: 19200417]

31. Rosenberg RD, Lando JF, Hunt WC, Darling RR, Williamson MR, Linver MN, et al. The New Mexico Mammography Project. Screening mammography performance in Albuquerque, New Mexico, 1991 to 1993. Cancer. 1996; 78(8):1731–9. [PubMed: 8859186]

32. Sylvester PA, Kutt E, Baird A, Vipond MN, Webb AJ, Farndon JR. Rate and classification of interval cancers in the breast screening programme. Ann R Coll Surg Engl. 1997; 79(4):276–7. [PubMed: 9244072]

33. Wernli KJ, DeMartini WB, Ichikawa L, Lehman CD, Onega T, Kerlikowske K, et al. Patterns of breast magnetic resonance imaging use in community practice. JAMA Intern Med. 2014; 174(1): 125–32. [PubMed: 24247555]

Appendix A. Procedure Codes Used in This Analysis

Procedure	ICD-9 Procedure Codes	CPT Codes	DRG Codes
MRI		76093, 76094, 76498, 77021, 77058, 77059, 0159T, C8903–C8908	
Mammogram	87.37, 793.80, 793.82, V76.11, V76.12	76082, 76083, 76085, 76090–76092, 77051, 77052, 77055–77057, 3014F, 3340F–3345F, 3350F, 5060F, 5062F, 7020F,7025F, G0202–G0207, G0236, G8111– G8114, S8075	
Ultrasound	88.73	76645	
Biopsy	40.11, 40.22,40.3, 40.51, 85.1, 85.11, 85.12, 85.19, 85.2– 85.25, 85.31, 85.32, 85.91, 85.99, 87.35	10021, 10022, 19000, 19001, 19030, 19100–19103, 19105, 19110, 19112, 19120–19126, 19260, 19271,19272, 19290–19295, 19499, 38500, 39505, 38510, 38525, 38530, 38740, 38792, 76087–76089, 76095–76098, 76360, 76393, 76942, 77012, 77021, 77031, 77032, 77053, 77054, 0046T, 0047T	261, 262, 584, 585

Table 1

Characteristics of Women with an Interval Cancer or Screen-detected Cancer (N=1458)

	Interval Cancer Diagnosis		Screen-detected Cancer Diagnosis		Total	
Patient Characteristics[α]	**N**	**%**	**N**	**%**	**N**	**%**
Total	204	14	1254	86	1458	100
Preoperative MRI[β]						
No	161	78.9	1092	87.1	1253	85.9
Yes	43	21.1	162	12.9	205	14.1
Age (at diagnosis)						
66–69	52	25.5	338	27.0	390	26.8
70–74	59	28.9	324	25.8	383	26.3
75–79	48	23.5	294	23.4	342	23.5
80+	45	22.1	298	23.8	343	23.5
Race						
White, non-Hispanic	169	90.4	976	87.5	1145	87.9
Non-White	18	9.6	139	12.5	157	12.1
Education						
<High School	12	7.0	91	8.9	103	8.6
HS grad or GED	43	25.2	319	31.2	362	30.4
Some College/Technical	47	27.5	268	26.3	315	26.4
College grad or post graduate	69	40.4	343	33.6	412	34.6
Parity (ever given birth)						
No	20	16.5	120	15.4	140	15.5
Yes	101	83.5	662	84.6	763	84.5
Age at Menarche						
<14	63	77.8	396	74.7	459	75.1
≥14	18	22.2	134	25.3	152	24.9
First-degree Family History of Breast Cancer						
No	155	76.7	933	75.1	1088	75.3
Yes	47	23.3	310	25.9	357	24.7
Co-Morbidities (1 year prior dx date) [28]						

	Interval Cancer Diagnosis		Screen-detected Cancer Diagnosis		Total	
Patient Characteristics[a]	**N**	**%**	**N**	**%**	**N**	**%**
0	134	65.7	870	69.4	1004	68.9
1	52	25.5	273	21.8	325	22.3
2+	18	8.8	111	8.9	129	8.9
Five Year Breast Cancer Risk [26]						
Low Risk (cutoff = 1.67)	11	6.9	116	11.9	127	11.2
High Risk	149	93.1	856	88.1	1005	88.8
Mammographic Breast Density						
Fatty/ Scattered	86	50.3	653	61.8	739	60.2
Heterogeneously Dense /Extremely Dense	85	49.7	404	38.2	489	39.8
Personal History of Biopsy						
No	122	61.9	837	70.9	959	69.6
Yes	75	38.1	343	29.1	418	30.4

[a] Missing (N): Race (156); Education (266); Parity (555); Menarche age (847); Family history (13); Five year risk (326); Breast density (230); Personal history of biopsy (81).

[β] Preoperative MRI was defined as a claim found between diagnosis date and date of primary surgical treatment.

Table II

Cancer Characteristics for Women with an Interval Cancer or Screen-detected Cancer (N=1458)

	Interval Cancer Diagnosis		Screen-detected Cancer Diagnosis		Total	
Characteristics[a]	**N**	**%**	**N**	**%**	**N**	**%**
Total	204	14	1254	86	1458	100
Cancer Type						
DCIS	23	11.3	274	21.9	297	20.4
Invasive Lobular	51	25.0	175	13.8	226	15.5
Invasive Other (including invasive ductal	130	63.7	805	64.2	935	64.1
Stage						
0	23	11.4	274	22.2	297	20.7
I	82	40.1	708	57.3	790	55.0
II/III/IV	96	47.8	253	20.5	349	24.3
ER						
Positive/elevated	155	81.2	1021	88.6	1176	87.5
Negative/normal	36	18.9	132	11.5	168	12.5
PR						
Positive/elevated	135	71.1	864	75.9	999	75.2
Negative/normal	55	29.0	274	24.1	329	24.8
HER2/Neu						
Positive/elevated	SCS[β]	SCS	SCS	SCS	58	9.8
Negative/normal	SCS	SCS	SCS	SCS	536	90.2
Tumor Size						
<5mm	14	6.9	131	10.9	145	10.3
5–9mm	14	6.9	325	27.0	339	24.1
10–14mm	36	17.8	293	24.3	329	23.4
15–19mm	43	21.3	210	17.4	253	18.0
20mm+	95	47.0	247	20.5	342	24.3
Grade						
Grade 1 well-differentiated	42	21.9	311	26.8	353	26.1
Grade 2 moderately-differentiated	86	44.8	560	48.3	646	47.8

Characteristics[α]	Interval Cancer Diagnosis		Screen-detected Cancer Diagnosis		Total	
	N	%	N	%	N	%
Grade 3 poorly-differentiated	64	33.3	289	24.9	353	26.1
Nodal Status						
No positive nodes	160	78.4	1095	87.3	1255	86.1
≥ 1 positive nodes	44	21.6	159	12.7	203	13.9
Breast Cancer Laterality						
Unilateral	SCS	SCS	SCS	SCS	1421	97.5
Bilateral	SCS	SCS	SCS	SCS	37	2.5

[α]Missing (N): Stage (22); ER (130); PR (130); Her2/Neu (864); Tumor size (50); Grade (106).

[β]SCS: Small cell size.

Table III

Additional Imaging, Additional Biopsies, and Primary Surgical Treatment in Relation to Preoperative MRI for Women with an Interval Cancer or Screen-detected Cancer

	Interval Cancer Diagnosis				Screen-detected Cancer Diagnosis			
	MRI (N=43; 21.3%)		No MRI (161; 78.9%)		MRI (N=162; 12.9%)		No MRI (N=1092; 87.1%)	
	N	%	N	%	N	%	N	%
Additional Imaging (Mammogram/Ultrasound)	13	30.2	35	21.7	67	41.4	309	28.3
Additional Biopsies	SCS[a]	SCS	95	59.0	150	92.6	725	66.4
Primary Surgical Treatment								
Breast conserving surgery	26	60.5	95	59.8	120	74.5	852	78.2
Mastectomy	17	39.5	64	40.3	41	25.5	237	21.8

[a]SCS: Small cell size.