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Screening Breast MRI Outcomes in Routine Clinical Practice: Comparison to BI-RADS Benchmarks

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Abstract

Rationale and Objectives—*The BI-RADS Atlas 5th Edition* includes screening breast magnetic resonance imaging (MRI) outcome benchmarks. However, the metrics are from expert practices and clinical trials of women with hereditary breast cancer predispositions, and it is unknown if they are appropriate for routine practice. We evaluated screening breast MRI audit outcomes in routine practice across a spectrum of elevated risk patients.

Materials and Methods—This Institutional Review Board-approved, Health Insurance Portability and Accountability Act-compliant retrospective study included all consecutive screening breast MRI examinations from July 1, 2010 to June 30, 2013. Examination indications were categorized as gene mutation carrier (GMC), personal history (PH) breast cancer, family history (FH) breast cancer, chest radiation, and atypia/lobular carcinoma in situ (LCIS). Outcomes were determined by pathology and/or ≥12 months clinical and/or imaging follow-up. We calculated abnormal interpretation rate (AIR), cancer detection rate (CDR), positive predictive value of recommendation for tissue diagnosis (PPV2) and biopsy performed (PPV3), and median size and percentage of node-negative invasive cancers.

Results—Eight hundred and sixty examinations were performed in 566 patients with a mean age of 47 years. Indications were 367 of 860 (42.7%) FH, 365 of 860 (42.4%) PH, 106 of 860 (12.3%) GMC, 14 of 860 (1.6%) chest radiation, and 8 of 22 (0.9%) atypia/LCIS. The AIR was 134 of 860 (15.6%). Nineteen cancers were identified (13 invasive, 4 DCIS, two lymph nodes), resulting in CDR of 19 of 860 (22.1 per 1000), PPV2 of 19 of 88 (21.6%), and PPV3 of 19 of 80 (23.8%). Of 13 invasive breast cancers, median size was 10 mm, and 8 of 13 were node negative (61.5%).

Conclusions—Performance outcomes of screening breast MRI in routine clinical practice across a spectrum of elevated risk patients met the American College of Radiology Breast Imaging Reporting and Data System benchmarks, supporting broad application of these metrics. The indication of a personal history of treated breast cancer accounted for a large proportion (42%) of

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our screening examinations, with breast MRI performance in this population at least comparable to that of other screening indications.

Keywords

Screening breast MRI; outcomes; benchmarks

Introduction

Breast magnetic resonance imaging (MRI) is currently the most sensitive imaging test for identifying breast cancer, and detects malignancy that is occult to the clinical examination and other imaging modalities (1–3).

Several prospective studies have demonstrated an increase in the detection of breast cancer with breast MRI over mammography alone in patients with a familial or genetic predisposition for breast cancer (4–10). This has led to a rapid increase in the use of breast MRI across the country (11–13), particularly in those patients at high risk for the development of breast cancer (14).

In 2007, the American Cancer Society (ACS) published the first guidelines for breast MRI as an adjunct to mammography to screen patients for breast cancer (14). These guidelines recommend screening breast MRI in patients with a known genetic predisposition to breast cancer (BRCA mutation or Li-Fraumeni, Cowden, Bannayan-Riley-Ruvalcaba syndromes and their first-degree relatives), a lifetime risk for breast cancer ~20%–25% or greater, and radiation to the chest between the ages of 10 and 30 years old (14). Similar guidelines were subsequently enacted by the American College of Radiology (ACR) (15) and the National Comprehensive Cancer Network (NCCN) (16,17).

Although not traditionally considered at “high” risk for breast cancer, other groups of patients at higher than average risk for breast cancer include patients with a treated personal history of breast cancer and those with a history of biopsy-proven high-risk lesions (atypical ductal hyperplasia and lobular neoplasia). The ACS states that there is insufficient evidence for or against MRI screening in these patients (14) and the ACR states that screening MRI can be considered (15). The NCCN states that the utility of MRI in follow-up screening of women with prior breast cancer is undefined (18). However, recent data suggest that particularly those patients with a personal history of treated breast cancer constitute a significant proportion of patients being screened with breast MRI (19,20).

The importance and increasing use of breast MRI as an adjunct modality for the detection of breast cancer prompted the ACR to introduce a new breast MRI section in the *2003 Breast Imaging Reporting and Data System (BI-RADS) Atlas fourth edition* (21). The *ACR BI-RADS Atlas* is a quality assurance tool designed to standardize reporting, reduce confusion in breast imaging interpretation and management recommendations, and facilitate outcomes monitoring for mammography, ultrasound, and MRI (22). The appropriate use of BI-RADS assessment categories and management recommendations for breast MRI enables a medical practice to audit their program and monitor outcomes to improve the quality of patient care (23). Importantly, the ACR Breast MRI Accreditation Program requires accredited breast

MRI facilities to maintain a medical outcomes audit program to evaluate practice accuracy (24). This audit must include evaluation of the accuracy of interpretation as well as appropriate clinical indications for the breast MRI examinations.

Although outcomes and benchmarks are well established for screening mammography performance (23,25–27), breast MRI performance benchmarks are not well established and were not included in the 2003 *BI-RADS Atlas fourth addition*. In 2015, we published the results of a study to determine the breast MRI screening recommendations and subsequent outcomes in women at increased risk for breast cancer, but without a personal history of breast cancer, evaluated by oncology subspecialists at our center from 2007 to 2011 (28). In this patient cohort, seen by breast subspecialty providers, we found that screening breast MRI was recommended according to guidelines (primarily in premenopausal women with a family history or genetic predisposition to breast cancer), adherence was high, and cancer yield from breast MRI was similar to that in clinical trials (28).

The *BI-RADS Atlas fifth edition* was published in 2013 and introduced breast MRI screening benchmarks (23). The metrics are based on five prospective screening MRI clinical trials of women with a hereditary predisposition for breast cancer performed in specialized practices (4,6,10,29,30) outside the United States. It is unknown if these clinical trials' outcomes can be matched in routine clinical practice in the United States including across varied elevated risk patients, and BI-RADS acknowledges that these benchmarks may not be applicable across practices (31). The purpose of this study was to perform an audit of our screening breast MRI outcomes in routine clinical practice outside the trial setting. We included all patients undergoing screening breast MRI at our institution, regardless of ordering provider, resulting in a spectrum of elevated risk patients, including those with a personal history of breast cancer. Determining broadly generalizable outcome measures is essential as practices are required to audit their MRI programs and need appropriate and validated benchmarks with which to compare their results.

Materials and Methods

All consecutive screening breast MRI examinations performed at our institution between July 1, 2010 and June 30, 2013 were included in this Institutional Review Board-approved, Health Insurance Portability and Accountability Act-compliant study.

Breast MRI Indications

For all breast MRI examinations in the study period, we retrospectively reviewed our electronic medical record (Epic Systems Corporation, Verona, WI) and our mammographic information system (PenRad Technologies, Inc., Buffalo, MN) and categorized them as screening versus diagnostic MRI examinations based on reported clinical indications. We defined screening examinations as those in asymptomatic patients with a clinical indication of a known genetic mutation in the patient or patient's family, a family history of breast cancer, a personal history of treated breast cancer, history of chest radiation, and/or prior biopsy result of atypia or lobular carcinoma in situ (LCIS). For screening examinations with multiple indications, we used a hierarchy of gene mutation carrier > personal history of treated breast cancer > family history of breast cancer > history of chest radiation > atypia/

LCIS. For screening examinations for the clinical indication of a family history of breast cancer, medical records were reviewed to obtain patients' lifetime risk for breast cancer, if it was documented in clinic notes.

Of 1437 breast MRI examinations performed during the study period, 21 noncontrast examinations performed for evaluation of silicone implant integrity, 22 nondiagnostic examinations (reasons including patients unable to complete the examination, contrast extravasation or injection failure, and extreme patient motion), and two examinations without a final BI-RADS assessment were excluded. The records for 42 examinations that were ordered for screening but had a patient-reported symptom at the time of the examination were further reviewed. Twenty-one of 42 had long-standing nonsuspicious symptoms and/or a previous negative work-up, including diagnostic mammography and ultrasound, and remained categorized as screening MRI examinations. The remaining 21 of 42 were classified as diagnostic examinations, as were all MRI examinations for indications including a new diagnosis of breast cancer for evaluation of extent of disease, metastatic axillary carcinoma with unknown primary, response to neoadjuvant chemotherapy, short-interval follow-up of a previous MRI finding or benign MRI-guided biopsy, and other (such as problem solving) and were excluded (532 diagnostic examinations total).

Thus, the remaining 860 screening breast MRI examinations comprised the study cohort.

Breast MRI Technique

All study examinations were performed on a 1.5-T GE scanner (GE Healthcare, Waukesha, WI) using a dedicated breast coil (7 or 8 Channel, Invivo, Peawaukee, WI, July 2010 through January 2011; 8 Channel Sentinelle, Hologic, Inc., Bedford, MA, February 2011 through June 2013). A weight-based dose (0.1 mmol/kg) of a gadolinium-based contrast agent (gadobenate dimeglumine [MultiHance], Bracco Diagnostics, Inc., Monroe Township, NJ) was power injected at 2 cc/second followed by a 20 cc saline flush. From July 2010 through August 2011, a primarily sagittal imaging protocol was used with a field of view of 16–20 cm. Precontrast sequences included a 3-plane localizer, sagittal T2-weighted 2d fast spin echo (FSE) with fat saturation (repetition time [TR] = 5600 msec; echo time [TE] = 120 msec; echo train length [ETL] = 14; frequency × phase-encoding matrix = 256 × 224; slice thickness [ST] = 4 mm) and diffusion weighted imaging (B = 0; B = 1000) of each breast. Next, bilateral, simultaneous sagittal T1-weighted 3d spoiled turbo gradient echo imaging (Volume Imaging for Breast Assessment [VIBRANT], GE Healthcare) with and without chemical fat saturation prior to contrast administration, and eight times following contrast injection with approximately 70 second (s) temporal resolution (TR = 6.4; TE = 3.1; flip angle [FA] = 10°, bandwidth [BW] = 31; parallel imaging [ASSET, GE Healthcare] = 2 × 1; frequency × phase encoding matrix 256 × 160; ST = 3 mm). Delayed high-resolution axial and sagittal T1-weighted fast spoiled gradient echo sequences with fat saturation (VIBRANT) were also obtained with the same sequence specifications but a frequency × phase-encoding matrix = 288 × 224 and 2 mm slice thickness (sagittal) and 320 × 256 matrix and 2 mm slice thickness (axial) was performed. In August 2011, the protocol transitioned to an axial protocol including the following precontrast sequences with a standard 32 cm FOV (increased to 34 or rarely 36 cm only if necessary). Pulse sequences

included a 3-plane localizer, bilateral axial T2-weighted 2d FSE with fat saturation (TR = 4000 msec; TE = 85 msec; ETL = 16; frequency × phase-encoding matrix 320 × 224; ST = 2.4 mm), diffusion weighted imaging (B = 0; B = 1000), and bilateral axial 3d T1-weighted FSPGR (VIBRANT) sequences with and without chemical fat saturation. Postcontrast T1-weighted FSPGR (VIBRANT) sequences were repeated three times with approximately 180-second temporal resolution (TR = 6.8 msec; TE 3.3 = msec; flip angle 10°; BW = 50; parallel imaging = 2 × 1, matrix 384×384; slice thickness = 1.6 mm). Computer-aided evaluation (DynaCAD, Invivo, Gainesville, FL, July 2010 through January 2011; Aegis, Hologic, Inc., February 2011 through June 2013) was performed for temporal kinetic evaluation and creation of reformats, including subtraction and maximum intensity projection images.

Breast MRI Interpretation and Data Collection

All breast MRI examinations were prospectively interpreted and reported according to the *ACR BI-RADS Atlas* in conjunction with the patient's clinical history and other breast imaging studies, when available, including mammography and ultrasound. Although the fifth edition of the *BI-RADS Atlas* was released in 2013 (32), the majority of examinations in our study were interpreted according to the fourth edition of the *BI-RADS Atlas* (21). All examinations were prospectively assigned a final BI-RADS assessment category by one of nine radiologists specializing in breast imaging with 1–20 years of experience interpreting breast MRI. Tissue diagnosis (typically image-guided biopsy) was recommended for all suspicious lesions (BI-RADS categories 4 and 5). Probably benign lesions (BI-RADS category 3) were typically managed with a short-term follow-up MRI.

Patient age, the breast MRI examination's final BI-RADS assessment category, and lesion features including type and size were recorded from prospectively collected information from the electronic medical record (Epic Systems Corporation) and mammographic information system (PenRad Technologies, Inc.). If the MRI examination had multiple lesions with more than one BI-RADS category, the single BI-RADS assessment for this study was categorized according to the hierarchy 5>4>0>6>3>2>1. Dates of follow-up examinations, subsequent biopsy dates and guidance modality, and biopsy results were also recorded. If the percutaneous biopsy result was malignant, the histologic subtype, axillary nodal status, and invasive cancer size were recorded. If a concerning lesion recommended for biopsy did not undergo percutaneous biopsy but instead underwent surgery, the surgical pathology result was correlated with the MRI findings in an attempt to determine final lesion outcome. Final benign versus malignant outcome was ascertained by pathology, if percutaneous biopsy or surgery was performed. If tissue sampling was not performed, outcomes were determined by the presence or absence of cancer within 365 days of the breast MRI by follow-up imaging and review of the clinical record.

Calculations

The proportion of screening breast MRI examinations for each elevated risk indication was calculated. Screening audit statistics were computed using the classifications and definitions in the fifth edition of the *ACR BI-RADS Atlas* (32). BI-RADS categories 1 and 2 are negative and categories 4 and 5 are positive. BI-RADS category 0 and category 3 are also

considered positive for the screening audit because they are associated with the recommendation for additional imaging before the next routine screening examination. The abnormal interpretation rate was calculated by dividing the total number of positive examinations (those with a final BI-RADS category of 0, 3, 4, or 5) by the total number of screening examinations performed. PPV2 (biopsy recommended) was calculated as the number of cases with a diagnosis of cancer (within 1 year) divided by the number of screening examinations recommended for tissue diagnosis (BI-RADS categories 4 and 5). PPV3 (biopsy performed) was calculated as the number of cases with a diagnosis of cancer divided by the number of biopsies performed.

The cancer detection rate, or the number of cancers detected at imaging per 1000 breast MRI examinations, was calculated as the number of cancers detected divided by the total number of screening MRI examinations multiplied by 1000. For cancers within the breast (excluding two malignant lymph nodes), median size of the invasive cancers, percentage of node-negative invasive cancers, percentage of minimal cancer (invasive cancer ≤ 1 cm or ductal carcinoma in situ (DCIS)), and percentage stage 0 or 1 cancer were calculated according to BI-RADS definitions.

Results

A total of 860 screening breast MRI examinations were included in the study. They were performed in 566 women with mean age of 47 (range 18–83) years. The screening breast MRI examination indications and proportion of examinations for each indication are detailed in Table 1. The most common indications for a screening MRI were a family or a personal history of breast cancer; of the 365 examinations performed in patients with a personal history of breast cancer, 52 (14.2%) also had a family history of breast cancer.

For the 106 examinations performed for the indication “genetic mutation carrier,” two examinations were performed in one patient with a CDH-1 mutation, one examination was performed in one patient with Li-Fraumeni syndrome, and two examinations were performed in two patients with a family history of a *BRCA* gene mutation, but the patients themselves were untested (both had mothers with a known BRCA gene mutation). The remaining 101 breast MRI examinations in this category were performed in patients with a known *BRCA1* or *BRCA2* gene mutation. Of the 367 examinations performed for a family history of breast cancer, 258 (70.2%) had the lifetime risk for breast cancer documented in the clinical records. In four of 258 examinations (1.6%), lifetime risk was below 20% (10% to 18.5%). In the remaining 254 examinations (98.4%), lifetime risk for breast cancer was greater than or equal to 20%.

Seven hundred twenty-six (84.4%) of the 860 screening MRI examinations were given a BI-RADS assessment category 1 or 2 (negative or benign, respectively). There were no malignancies detected in the BI-RADS category 1 or 2 exams.

Forty-three (5%) of the 860 examinations were given a BI-RADS assessment category 3 (probably benign). Three were ultimately biopsied (one by patient choice; two because the

MRI finding was identified on subsequent ultrasound and assessed as BI-RADS category 4, suspicious). There were no malignancies detected in the BI-RADS category 3 exams.

Seven (0.8%) of the 860 examinations were assessed as BIRADS category 0 (need additional imaging). Three of seven underwent biopsy or fine needle aspiration for findings identified on subsequent ultrasound assessed as BI-RADS category 4 (suspicious), all three with benign results. Three of seven had benign or negative findings on subsequent ultrasound and follow-up. The final screening MRI examination assessed as a BI-RADS category 0 was performed in a patient with a personal history of treated stage I right breast invasive ductal carcinoma with a suspicious right axillary lymph node. This was confirmed and biopsied with ultrasound guidance, and was found to be a malignant (metastatic) axillary lymph node.

Eighty-four (21.4%) examinations were given a BI-RADS assessment category 4 (suspicious) or 5 (highly suggestive of malignancy), and 18 were found to be malignant. One of these was a malignant (metastatic) internal mammary lymph node.

Thus, there were 19 total screen detected malignancies, summarized in Table 2. There were 17 in-breast malignancies, one metastatic axillary lymph node, and one metastatic internal mammary lymph node. Of the 17 in-breast cancers, 13 were invasive and four were DCIS alone. Seventy point six percent (12/17, 70.6%) were “minimal” cancers, defined by the *BI-RADS Atlas* (32) as DCIS and/or invasive cancers ≤ 1 cm in size. Of the 13 invasive in-breast cancers, the median size was 10 mm and eight were node negative (8 of 13, 61.5%).

There were 134 positive examinations (BI-RADS categories 0, 3, 4, and 5). The AIR was 15.6% (134 of 860 screening MRI examinations). If BI-RADS Category 3 examinations were not considered positive (common prior to the 2013 edition of the *BI-RADS Atlas*), the abnormal interpretation rate was 10.6% (91 BI-RADS categories 0, 4, 5 examinations/860 screening MRI examinations). Eighty-eight of the 134 positive examinations resulted in a recommendation for tissue sampling. PPV2 was 21.6% (19 cancers/88 recommendations for biopsy) and PPV3 was 23.8% (19 biopsy-proven cancers/80 biopsies performed). Cancer detection rate was 19 of 860, or 22.1 per 1000 screening examinations. These results are summarized in Table 1 and are compared to the BI-RADS benchmarks in Table 3.

Cancer detection rate and PPV3 were also calculated separately for the two largest elevated risk subgroups in our study (personal history and family history of breast cancer). The cancer detection rate was 30.1 per 1000 examinations (11 cancers/365 exams) and PPV3 was 42.3% (11 cancers/26 biopsies performed) in patients with a personal history of breast cancer. The cancer detection rate was 16.3 per 1000 exams (6 cancers/367 exams) and PPV3 was 14.3% (6 cancers/42 biopsies performed) in patients with a family history of breast cancer.

Discussion

Our clinical practice audit of screening breast MRI outcomes in routine clinical practice supports the value of the benchmark metrics introduced in the 2013 *BI-RADS Atlas fifth edition* (23). These benchmarks were based on the analysis of five prospective screening

MRI trials of women with a hereditary predisposition for breast cancer enrolled in clinical trials at specialized screening MRI practices (4,6,10,29,30) in Europe and Canada. To date, it has not been known whether the BI-RADS metrics would be applicable in routine practice in the United States outside of the research setting, and with a spectrum of patients at elevated risk. Only one prior study has assessed breast MRI audit performance measures in broad practice, using MRI examinations from 2007 to 2008 (20). Our clinical practice audit, evaluating screening examinations from 2010 to 2013, demonstrated that cancer detection rate, median invasive cancer size, PPV2, and PPV3 all fell within the ACR BI-RADS MRI benchmarks (23), supporting their broader appropriateness for routine practice (Table 3) in the United States.

Our cancer detection rate of 22.1 cancers per 1000 examinations was in the benchmark range of 20–30 cancers per 1000 examinations. Our PPV2 (biopsy recommended) of 21.6% met the benchmark of 15%, and our PPV3 (biopsy performed) of 23.8% was in the benchmark range of 20%–50%. In 2014, Niell et al. published the results of an audit of their breast MRI practice (20). Their PPV2 and PPV3 for screening breast MRI were 24% and 27% respectively, similar to our results and additionally supporting the use of the BI-RADS benchmarks. Their cancer detection rate of 14 cancers per 1000 screening MRI examinations was lower than the BI-RADS benchmark; however, our results confirm that performance within the BI-RADS benchmark can be obtained. Differences in results may be due to patient populations and study intervals, with their study performed with data from 2007 to 2008 and our study including data from 2010 to 2013.

Other quality metrics in the BI-RADS audit include median size of invasive cancers, percentage of node-negative invasive cancers, and percentage of minimal cancers. Our result of 70.6% met the BI-RADS benchmark of greater than 50% for percentage of minimal cancers, defined as invasive cancer less than or equal to 1 cm or DCIS. However, our percentage of node-negative invasive cancers was 61.5%, lower than the BI-RADS benchmark of greater than 80%. The mammography benchmark for this metric is 77.3%, and BI-RADS states that MRI benchmarks should generally be in the range of those for mammography (23). Additionally, the clinical trials have found an approximately 15% node-positive rate for invasive cancers (33). It is possible that our result was influenced by our smaller sample size or our differing patient population compared to the clinical trials.

We also calculated the abnormal interpretation rate, defined as the proportion of examinations assigned BI-RADS categories 0, 3, 4, and 5. Although there is not currently a BI-RADS benchmark for this metric, assuming a CDR of 20–30 cancers per 1000 examinations, PPV of 20%–50%, and allowing for up to 2% of examinations designated BI-RADS 0 or 3, a reasonably proposed range could be 6%–17%. Our result of 15.6% is in this range, and includes BI-RADS category 3 and the relatively rare BI-RADS category 0 examinations. The *2013 BI-RADS Atlas* (23) defines category 3 at screening as a positive result to be included in the calculation of the AIR, because additional imaging is recommended before the next routine screening. If BI-RADS category 3 examinations were excluded, our AIR was 10.6%, also solidly within the proposed range estimated previously. Using data from 41 facilities across five Breast Cancer Surveillance Consortium imaging registries, Lee et al. (34) found a screening breast MRI AIR of 10.5% if BI-RADS category

3 examinations were excluded, and 21.0% if they were included. Niell et al. (20) found a similar abnormal interpretation rate of 12% when BI-RADS category 3 lesions were excluded.

The percentage of BI-RADS category 3 examinations in our study was 5% and no malignancies were identified in follow-up of these lesions. Although not a designated benchmark, BI-RADS states a desirable BI-RADS category 3 goal for MRI of 10%, decreasing over time in a mature program to a rate much closer to that currently achieved at mammog-raphy of 1%–2% (32). As radiologists become more experienced in the interpretation of MRI, the BI-RADS category 3 rate will likely decrease. This was demonstrated in the Niell et al. study, where 21% of the screening MRI examinations during the study interval were assessed as BI-RADS category 3, but in subsequent years the BI-RADS category 3 rate at their institution fell to less than 5% (20).

The performance outcomes of screening breast MRI in routine clinical practice will be influenced by the characteristics of the patient population. Our screening cohort was comprised of a substantial proportion of women with a personal history of treated breast cancer, accounting for over 42% of our screening breast MRI examination indications. This proportion is similar to that reported by Niell et al., with the largest proportion (46%) of screening breast MRI examinations at their institution performed in patients with a personal history of breast cancer (20). Lehman et al. also described a larger proportion of patients screened for a personal history of breast cancer compared to a genetic and family history (19). In our study, both the cancer detection rate and the PPV3 (biopsy performed) were higher in those patients undergoing breast MRI screening for a personal history of breast cancer versus those with a family history of breast cancer, (42.3% vs 14.3% for PPV3 and 3.0% vs 1.6% cancer yield, respectively). These results are similar to other single-site, retrospective studies (19,35,36). Overall, the performance of breast MRI in women with a personal history of treated breast cancer is promising and in support of consideration of this tool for supplemental screening.

There are limitations of our study. Our outcomes are from a single clinical practice in an academic center with MRI interpretation by radiologists that specialize in breast imaging, most of whom are fellowship trained. Thus, our results may not be generalizable to more broad practices. In addition, because we had a large proportion of examinations with a screening indication of personal history of treated breast cancer, practices with different mixes of high-risk patients may have different outcomes. We also did not differentiate between baseline and prevalence breast MRI screening examinations, two categories which may differ in their performance metrics. Finally, although we performed follow-up for all patients through imaging and the medical records, we did not have linkage to a regional cancer registry to definitely ascertain outcomes for negative examinations.

In summary, we report the results of an audit of our screening breast MRI examinations interpreted as part of routine clinical practice at our institution. Our results met the ACR BI-RADS audit benchmarks for cancer detection rate, PPV2, and PPV3, supporting the adoption of these benchmarks in routine clinical practice in the United States. Further, we describe our performance in other quality outcomes including abnormal interpretation rate

(BI-RADS categories 0, 3, 4, 5) of ~15% and proportion of examinations with a BI-RADS category 3 assessment of ~5%. We hope that these results play a role in the development of BI-RADS benchmarks for interpretation and BI-RADS category 3 utilization. Finally, we found that screening of women with a personal history of treated breast cancer accounted for a large proportion (42%) of our screening examinations, with breast MRI performance in this population at least comparable to that of other screened patients. These findings corroborate other recent results (19), and suggest that MRI may be an important tool to supplemental screening in patients with a personal history of breast cancer.

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Table 1

Screening Breast MRI Indications

Breast MRI Examination Indications	Patients, N	%	Cancer Yield	CDR	PPV3
Genetic mutation carrier	106	12.3	1		
Family history of breast cancer	367	42.7	6		
Personal history of treated breast cancer	365	42.4	11		
History of chest radiation	14	1.6	0		
Prior biopsy with atypia or LCIS	8	0.9	1		
Total screening	860	100.0	19	22.1	23.8

CDR, cancer detection rate (per 1000 examinations); LCIS, lobular carcinoma in situ; MRI, magnetic resonance imaging; PPV3, positive predictive value 3 (biopsy performed).

Table 2

Breast MRI Screen Detected Cancers

	Age	Screening Indication	Histology	Location	Invasive size (cm)	Node status	MRI Finding Type	BI-RADS
1	51	Personal history	Invasive recurrence	Axillary node		Positive	Lymph node	0
2	41	Personal history	IDC, ILC, DCIS	Breast	1.3	Positive	NME	4
3	55	Family history	DCIS	Breast		N/A	Mass	4
4	48	Family history	DCIS	Breast		N/A	Mass	4
5	59	Personal and Family history	DCIS	Breast		N/A	NME	4
6	62	Family history	IDC	Breast	0.5	Negative	Mass	4
7	57	Personal history	IDC, DCIS	Breast	0.5	Positive	Mass	4
8	55	LCIS	IDC	Breast	0.9	Negative	NME	4
9	57	Family history	IDC, DCIS	Breast	0.4	Negative	Mass	4
10	58	Personal history	IDC	Breast	0.4	Negative	NME	4
11	43	Personal history	IDC, DCIS	Breast	2.2	Negative	Mass	4
12	50	Gene mutation (BRCA1)	DCIS	Breast		N/A	NME	4
13	40	Family history	IDC	Breast	1	Positive	Mass	4
14	60	Personal history	IDC	Breast	1.4	Positive	Mass	4
15	54	Family history	IDC	Breast	1	Negative	Mass	4
16	63	Personal history	IDC	Breast	1.9	Negative	Mass	4
17	41	Personal history	Invasive recurrence	Internal mammary node		Positive	Lymph node	4
18	47	Personal history	IDC	Breast	0.8	Positive	Mass	5
19	65	Personal history	Invasive recurrence	Chest wall	1.6	Negative	Mass	5

BI-RADS, Breast Imaging Reporting and Data System; DCIS, ductal carcinoma in situ; IDC, invasive ductal carcinoma; ILC, invasive lobular carcinoma; MRI, magnetic resonance imaging; NME, nonmass enhancement; N/A, not applicable.

Table 3
BI-RADS Edition 5 Breast MRI Screening Benchmarks

Category	Benchmark'	Our Results
Cancer detection rate (per 1000 examinations)	20–30	22.1
Median size of invasive cancers (in mm)	TBD	10.0
Percentage of node-negative invasive cancers	>80%	61.5%
Percentage of minimal cancer *	>50%	70.6% (12 of 17)
PPV2 (recommendation for biopsy)	15%	21.6% (19 of 88)
PPV3 (biopsy performed)	20%–50%	23.8% (19 of 80)

BI-RADS, Breast Imaging Reporting and Data System; MRI, magnetic resonance imaging; PPV, positive predictive value; TBD, to be determined.

* Minimal cancer is invasive cancer ≤ 1 cm or ductal carcinoma in situ as per the American College of Radiology Edition 5 of the *BI-RADS Atlas*.