Published in final edited form as:

Clin Breast Cancer. 2015 April ; 15(2): 143–152. doi:10.1016/j.clbc.2014.11.003.

MRI-guided Breast Biopsy: Outcomes and Impact on Patient Management

Kelly S Myers, MD^{a,1}, Ihab R Kamel, MD PhD^b, and Katarzyna J Macura, MD PhD^c

^aThe Johns Hopkins Hospital, 600 North Wolfe St, Central Radiology, Room 118, Baltimore, MD 21287, USA, myersk@mskcc.org, 1 (914) 367-7264

^bThe Johns Hopkins Hospital, 600 N. Wolfe Street, MRI Room 143, Baltimore, MD 21287, USA, ikamel@jhmi.edu

^cThe Johns Hopkins Hospital, Russell H. Morgan Department of Radiology and Radiological Science, JHOC 3140C, 601 N. Caroline Street, Baltimore, MD 21287, USA, kmacura@jhmi.edu

Abstract

Introduction—The purpose of this study was to correlate the pathology results of magnetic resonance imaging (MRI)-guided breast biopsies at our institution to MRI findings and patient clinical history characteristics. The impact of MRI-guided breast biopsies on surgical management in patients with a new diagnosis of breast cancer was also assessed.

Patients and Methods—In this HIPAA-compliant study we retrospectively reviewed all MRI-guided breast biopsies performed 3/2006–5/2012. Clinical history, MRI features and pathology outcomes were reviewed. In patients undergoing breast MRI to evaluate extent of disease, any change in surgical management resulting from the MRI-guided biopsy was recorded. Statistical analysis included binary logistic regression and independent student's t-test.

Results—Two-hundred fifteen lesions in 168 patients were included, of which 23 (10.7%) were malignant, 43 (20%) were high risk, and 149 (69.3%) were benign. No clinical characteristic was associated with malignancy in our cohort. MRI features associated with malignancy were: larger size (mean 2.6 cm versus 1.3 cm, $p=0.046$), washout kinetics (18% malignancy rate, $p=0.02$) and marked background parenchymal enhancement (40% malignancy rate, $p\text{-value} < 0.001$ to 0.03). Nineteen (28%) of the 67 patients with a new diagnosis of breast cancer undergoing MRI-guided breast biopsy had a change in surgical management based on the biopsy result.

© 2014 Elsevier Inc. All rights reserved.

Correspondence to: Kelly S Myers.

¹Present address: Memorial Sloan Kettering Cancer Center – West Harrison, 500 Westchester Ave, West Harrison NY 10604

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Conflict of Interests

Disclosures: Authors KJM and IRK had a financial relationship with commercial organizations that may have direct or indirect interest in the content: author KJM had a research grant from Siemens (Munich, Germany).

Conclusions—Malignancy rate was associated with lesion size, washout kinetics and marked background enhancement of the breast parenchyma but was not associated with any clinical history characteristics. Pre-operative MRI-guided breast biopsies changed surgical management in 28% of women with a new diagnosis of breast cancer.

Introduction

Breast magnetic resonance imaging (MRI) is commonly used for breast cancer screening in high risk patients and to evaluate the extent of disease in patients with a new diagnosis of breast cancer. Although MRI has a high reported sensitivity for breast cancer of 0.90 (95% confidence interval: 0.88, 0.92), it has a lower specificity of 0.72 (95% confidence interval: 0.67, 0.77), and biopsy is often required to establish a diagnosis.^{1,2} When a suspicious lesion is visible only on MRI, MRI-guided biopsy is a fast and safe option for diagnosis.

The reported malignancy rate of MRI-guided breast biopsies varies from 18 to 60%, with most studies reporting malignancy rates of 20–35%.^{3–11} The variation is probably related to differences in patient populations, study designs and radiologist thresholds for recommending biopsy. Per the American College of Radiology BI-RADS Atlas 2013, the benchmark for the malignancy rate of MRI-guided biopsies performed (also known as the biopsy yield of malignancy or positive predictive value 3 (PPV₃)) is 20–50%.¹²

MRI-guided breast biopsies are often performed in women with a new diagnosis of breast cancer, although the role of breast MRI in this patient population is controversial. While several studies have demonstrated that pre-operative breast MRI changes surgical management in 10–34%,^{13–17} some argue that this change in surgical plan does not change patient outcomes.^{18–20} Additional studies evaluating the role of breast MRI in this patient population and its subsequent clinical impact are needed.

The purpose of this study was to correlate the pathology results of magnetic resonance imaging (MRI)-guided breast biopsies at our institution to MRI findings and patient clinical history characteristics. The impact of MRI-guided breast biopsies on surgical management in patients with a new diagnosis of breast cancer was also assessed.

Patients and Methods

Subjects

This HIPAA-compliant study was approved by the Institutional Review Board at Johns Hopkins Hospital. A database search for all MRI-guided breast biopsy exams from March 2006 to May 2012 was performed, which identified 261 potentially eligible lesions. In order to be eligible, lesions must have been successfully biopsied by MRI-guidance (MRI-guided core biopsy or MRI-guided localization with subsequent surgical biopsy), have available images from the MRI exam on which the biopsy was recommended, and have available pathology results. Forty-six lesions were excluded for the following reasons: images were from an MRI-guided biopsy performed at an outside institution (n=15), biopsied lesions were identified on outside images which were not available (n=15), procedure was MRI-guided clip placement without direct pathology (n=6), unsuccessful biopsy attempts (n=6) or

exams of localizations for known cancers or lesions which had already undergone biopsy (n=4). This study included suspicious, BIRADS-4 or 5 lesions that were only visualized by MRI. Therefore, suspicious lesions detected by MRI for which second look ultrasound and subsequent ultrasound guided biopsy were performed were excluded. For the 215 eligible lesions, the original breast MRI which identified the suspicious lesion undergoing MRI-guided breast biopsy was then identified.

MRI-Guided Breast Biopsy

Patients were scanned on a 1.5 Tesla MRI system (Intera, Philips Medical Systems, Best, The Netherlands) in prone position using a bilateral seven-channel phased array breast coil (InVivo, Orlando, FL). As part of the patient preparation for a unilateral MRI-guided breast biopsy, we applied compression on the examined breast and for patients presenting for bilateral biopsies, compression was applied to both breasts. The MRI protocol included a high spatial-resolution scan for 2.5 minutes before and 10 seconds after contrast administration, followed by an additional high spatial-resolution scan to assess the delayed phase of enhancement. High spatial resolution, three-dimensional (3D), T1-weighted spoiled gradient echo (GRE) scans with fat suppression were acquired in the transverse plane (TR/TE: 7.08/ 3.56; flip angle(FA)=10°; slice thickness(ST)=2 mm; FOV=35 × 35 cm; and matrix size=512 × 512) before and after intravenous administration of gadobenate dimeglumine (Gd-BOPTA, Multihance; Bracco Imaging Spa, Milan, Italy) at a rate of 0.2 ml/sec and a dose of 0.1 mMol/Kg. Post-processing with subtraction of pre-contrast images from post-contrast images was performed. Following lesion localization and placement of an introducer to the target as previously reported.²¹ Biopsies were performed with a 10 gauge vacuum-assisted core biopsy device (Vacora, Bard, Arizona) with an average 6 core biopsies per lesion. Biopsies were performed by one of 4 radiologists with an average experience of 4 years (range 2 to 12).

Data Collection and Analysis

A retrospective chart review was performed for the 215 eligible lesions in 168 patients. Clinical information including age, risk factors for breast cancer, previous or current diagnosis of breast cancer and indication for the MRI was recorded. For patients with a new diagnosis of breast cancer undergoing breast MRI for evaluation for extent of disease, surgical plan prior to the breast MRI and following the MRI-guided breast biopsy were recorded.

The MRIs were originally interpreted by one of 4 radiologists with an average experience of 4 years (range 2 to 12). Once the eligible breast MRI exams were identified, a second reader retrospectively characterized all lesions reported during the original interpretation according to the BIRADS lexicon, and also recorded lesion kinetics, lesion T2 signal, comparison to prior MRI exams, background parenchymal enhancement and breast density. Lesion T2 signal was categorized as low, intermediate or high signal as compared to background parenchymal T2 signal. Background parenchymal enhancement was subjectively assessed according to the BIRADS definitions of minimal (0–25%), mild (26–50%), moderate (51–75%) and marked (76–100%).²² The second reader was blinded to pathology outcomes. The

lesion characterization recorded by the second reader was used for all statistical analyses. The number of months of MRI follow-up for all lesions was also recorded.

Pathology from the MRI-guided core biopsy and surgery were recorded, with the final pathology reflecting surgery pathology, when available. High risk lesions on core biopsy which showed malignancy at surgery were considered to be upgraded. During the time of this study (March 2006 to May 2012), lesions at core biopsy which were considered to be high risk at our institution and for which surgical excision was considered included: atypical ductal hyperplasia (ADH), atypical lobular hyperplasia (ALH), atypia not otherwise specified (atypia NOS), atypical vascular proliferation, lobular carcinoma in situ (LCIS), papilloma, micropapilloma, complex sclerosing lesion and radial scar.

Statistical Analysis

Correlations between malignancy rate and clinical information, as well as malignancy rate and imaging features, were assessed using binary logistic regression for categorical variables. A generalized linear model with general estimating equations was used to account for within patient correlations of lesions. Correlations between malignancy rate and lesion size, as well as malignancy rate and patient age, were assessed using independent student's t-tests.

Results

Patients

A retrospective review yielded 261 potentially eligible MRI-guided breast biopsies with 46 lesions excluded, resulting in 215 eligible lesions in 168 patients. The mean age was 51 years (range 21–76), with no association of age with malignancy (mean 51 years (standard deviation (SD) 9.9), for benign lesions versus 53 years (SD 10), for malignant lesion, $p=0.43$). The indication for breast MRI was: extent of disease (86/168, 52%), high risk screening (49/168, 29%), diagnostic work-up of an indeterminate imaging or physical exam finding (14/168, 8%), follow-up (9/168, 5%), nipple discharge (4/168, 2%), pain (2/168, 1%), research study participant (1/168, 1%) or unknown primary cancer site (1/168, 1%), with the indication unknown in 2/168 (1%). In those with available clinical history, there was a strong family history of breast cancer in 33/140 (24%) and personal history of atypia in 22/144 (15%). In our cohort, there was no association with any clinical characteristic and malignancy (Table 1), other than a higher malignancy rate in patients in whom the original MRI was performed for short-term follow-up compared to high risk screening.

Histopathology of MRI-guided Core Biopsy

MRI-guided core biopsies were performed on 200 lesions (Figure 1), of which 16/200 (8.0%) were malignant: 9/200 (4.5%) were invasive ductal carcinoma (IDC), 5/200 (2.5%) were ductal carcinoma in situ (DCIS) and 2/200 (1%) were invasive mammary carcinoma with mixed ductal and lobular features (IMC, Table 2). Thirty-nine (19.5%) of the 200 core biopsied lesions were high risk, with the predominant pathologies being atypical lobular hyperplasia (ALH, 7/200, 3.5%), atypical ductal hyperplasia (ADH, 7/200, 3.5%), papilloma (10/200, 5%) and complex sclerosing lesion (5/200, 2.5%). Benign findings were seen in

72.5% of the core biopsies, with fibrocystic change (62/200, 31%), benign breast tissue (31/200, 15.5%) and stromal fibrosis (16/200, 8%) being the most common.

Histopathology at Surgery

Rather than undergoing core biopsy, 15 suspicious lesions seen on breast MRI underwent surgical biopsy following MRI-guided needle localization (n=7) or MRI-guided clip placement with subsequent mammographic wire localization (n=8). Three (20%) of the 15 were malignant (IDC (n=1), carcinoma (n=1) and DCIS (n=1)), 6/15 (40%) were high risk (ALH (n=3) and ADH (n=3)) and 6/15 (40%) were benign (fibrocystic change (n=3), stromal fibrosis (n=2) and benign breast tissue (n=1)).

In total, 59 lesions underwent surgery, including the 15 lesions which had a surgical biopsy and 44 lesions which had a previous MRI-guided core biopsy. The 44 core-biopsied lesions which underwent surgery included: 14/16 malignant lesions on core biopsies (1 patient had surgery elsewhere, another patient was lost to follow-up), 27/39 high risk lesions on core biopsy, with 8 patients choosing to forego surgery and 4 patients lost to follow-up, and 3 benign lesions which were interpreted as discordant.

At surgery, direct pathology was not available for 4/27 high risk lesions due to the lesion being included in a larger specimen (lumpectomy or mastectomy) without direct pathology reported for the excised high risk lesion. Two (8.7%) of the 23 high risk lesions were lesions which did not contain atypia on core biopsy and were found to contain atypia at surgical excision. Four (17.4%) of the 23 high risk lesions were upgraded to malignancy at surgery (3 to DCIS, 1 to IDC). One (20%) of the 5 DCIS lesions on core biopsy was upgraded to IDC. Of the 3 lesions with benign core biopsy pathology which were interpreted as discordant, 1 was a papilloma at surgical excision, 1 contained ADH and 1 was fibrocystic change. Including all lesions which underwent MRI-guided biopsy or MRI-guided localization, the final pathologies were malignant in 10.7%, high risk in 20% and benign in 69.3% (Figure 1, Table 2).

Follow-up

Of the 145 lesions with benign pathology on core biopsy, 43 lesions had MRI follow-up for an average time of 20.5 months (range 4 to 67 months). Three patients with benign core biopsies had new diagnoses of breast cancer during the follow-up period, one of which was possibly in the area of the previous biopsy.

Imaging Features

Of the 215 lesions undergoing MRI-guided core biopsy or localization, 79/215 (37%) were masses, 96/215 (44%) were nonmass enhancement and 40/215 (19%) were foci. There was no association between the malignancy rate and the type of lesion on MRI ($p=0.82-0.94$). MRI features associated with malignancy were: larger size (mean 2.6 cm, standard deviation (SD) 2.9 in malignant lesions versus mean 1.3 cm, SD 1.2 in benign lesions, $p=0.046$), washout kinetics (18% malignancy rate versus 7% in those without washout kinetics, $p=0.02$) and marked background enhancement of the breast parenchyma (40% malignancy rate versus 14% ($p=0.03$), 4% ($p<0.001$) and 8% ($p=0.002$) in patients with minimal, mild

and moderate enhancement, respectively, Table 3). The association of malignancy rate with larger size remained statistically significant when all lesions types were included together (mean 2.6 cm, standard deviation (SD) 2.9 in malignant lesions versus mean 1.3 cm, SD 1.2 in benign lesions, $p=0.046$), and when evaluated within masses (mean 1.9 cm, SD 2.4 in malignant mass versus mean 0.9 cm, SD 0.3 in benign masses) as well as within nonmass enhancement (mean 4.1 cm, SD 3.2 in malignant nonmass enhancement versus mean 2.1 cm, SD 1.5 in benign nonmass enhancement), although there was a considerable overlap in the range of lesion size among benign and malignant lesions (Figure 2). There was a trend for a higher malignancy rate in masses with a spiculated margin (31% malignancy rate versus 7% and 8% in those with a smooth or irregular margin, respectively, $p=0.05-0.06$) and a lower malignancy rate in masses or foci with a high T2 signal (6% malignancy rate versus 20% in those with intermediate or low T2 signal, $p=0.06$).

Change in Surgical Plan

Of the 67 patients undergoing MRI for extent of disease in whom pre-MRI surgical plan was known, the surgical plan was changed in 19/67 (28%, Figure 3). A plan for lumpectomy was changed to mastectomy in 5/19 (7.5%, Figure 4). Additional lumpectomies were performed in 4/19 patients (6%, Figure 5) and additional surgical excisions were performed in 5/19 (7.5%), including 1 patient who required 2 additional sites of surgical excision. 1 patient originally planned for a mastectomy, but after the MRI-guided biopsy yielded contralateral breast cancer, she opted for bilateral lumpectomies. One patient changed from a plan of mastectomy to lumpectomy after a benign MRI-guided biopsy. One patient planned for re-excision of surgical margins for DCIS, but after the MRI-guided biopsy yielded ADH, she required a larger surgical excision. One patient with a BRCA2 gene mutation and new diagnosis of breast cancer planned for contralateral prophylactic mastectomy, but after the MRI-guided biopsy demonstrated a high risk lesion, a contralateral sentinel node dissection was also performed at the time of surgery. One patient chose to have a contralateral mastectomy after the MRI-guided biopsy yielded a complex sclerosing lesion.

Discussion

The malignancy rate in our cohort of women with MRI-visible breast lesions who underwent MRI-guided biopsy or MRI-guided localization prior to surgery was 10.7% (8% at MRI-guided core biopsy and 20% of MRI-guided needle localization with surgical biopsy), which is lower than the reported range of 18 to 60%³⁻¹¹ and lower than the ACR BI-RADS® Atlas 2013 benchmark of 20–50%,¹² suggesting over-biopsying of lesions at our institution. Analyzing the characteristics of biopsied lesions with benign pathologies may help us identify lesions which may forego biopsies in the future.

There was a 17.4% upgrade rate of high risk lesions on core biopsy to malignancy at surgical excision, which is consistent with the reported upgrade rate of 7–25%.^{4, 9, 11, 23-25} Although at our institution we routinely obtain an average of 6 core biopsy samples, some institutions report obtaining as many as 12 samples.³ As our upgrade rate is within the reported range, this suggest that the lesions were adequately sampled with an average of 6 samples, although statistical analysis of our upgrade rate as it relates to the number of the

samples obtained was underpowered for definitive statistical analysis. Twenty percent (1/5) of DCIS lesions on MRI-guided core biopsy were found to be IDC at surgery, which is within the reported range of 17–25%.^{4, 10, 11, 26}

In our population, there was no statistically significant difference in the malignancy rate between patients undergoing the original MRI for extent of disease compared to high risk screening, although some prior studies have found a higher malignancy rate in those undergoing MRI for diagnostic, rather than screening, purposes.^{8, 11} There was a higher malignancy rate in patients in whom the original MRI was a short term interval follow-up compared to high risk screening exam (33% versus 5%, $p < 0.05$), although only 9 patients were in the follow-up category, and this analysis is probably underpowered. Of note, in 4/9 patients undergoing MRI-guided biopsy for a finding detected on a follow-up MRI, the biopsy was for a new finding. None of the known risk factors for breast cancers, including a family history of breast cancer and a personal history of atypia, were associated with malignant outcome from MRI-guided biopsy in our population, which could be related to the low overall malignancy rate in our study.

Several known suspicious MR-imaging features were associated with malignancy in our study, confirming the suspicious nature of these findings. However, in our study we evaluated only MRI-visible lesions which underwent biopsy by MRI-guidance or MRI-guided localization, as opposed to all suspicious lesions detected by MRI. Therefore, the features of suspicious lesions undergoing MRI-guided biopsies may not be representative of all lesions detected by MRI that were then confirmed to represent malignancy by other imaging guided procedures (i.e. ultrasound or stereotactic-guided biopsy), as reported in several prior studies. Spiculated margin was associated with malignancy, although with a lower positive predictive value (PPV 31%) than previously reported (91%).²⁷ Washout kinetics was associated with malignancy, although also with a lower PPV (18%) than previously reported (76%).² Larger size was also associated with malignancy, which has also been demonstrated in prior studies.^{11, 28} In our cohort, there was a strong association of marked background enhancement with malignancy, with a 40% malignancy rate among lesions in patients with marked background enhancement (compared to a malignancy rate of 4–14% in those with minimal, mild or moderate background enhancement). While the analysis of this association may be underpowered, with only 15 lesions in patients with marked background enhancement, this is consistent with previous studies which have found an association of marked background enhancement with increased malignancy rate.²⁹

In patients with a new diagnosis of breast cancer undergoing an MRI-guided breast biopsy, the biopsy changed the surgical plan in 28%. Recent studies have addressed the rate of change in surgical management among all breast cancer patients undergoing pre-operative breast MRI, (not only those undergoing MRI-guided breast biopsy) and have found a similar rate of change in surgical plan ranging from 26–34%.^{14–17} This again demonstrates the large impact that preoperative MRI, and MRI-guided breast biopsy, can have on the clinical care of this subset of patients. This change in surgical plan does not necessarily mean there is an improved clinical outcome in these patients, however, and long-term prospective studies will be needed to assess whether the additional disease detected by pre-operative breast MRI is directly related to improved clinical outcomes.

There are several limitations in our study. Only 69% of the high risk lesions on MRI-guided core biopsy underwent excision, which may introduce selection bias into the statistics regarding these high risk lesions. Additionally, a low number of benign lesions on core biopsy underwent follow-up MRIs. Lastly, we evaluated surgical plan changes only in patients undergoing MRI-guided breast biopsy, not in all women undergoing pre-operative breast MRI. Although this was not within the scope of the current study, the significant impact on surgical management is suggested and may warrant further investigation in the future.

Conclusion

Review of 215 MRI-guided breast biopsies at our institution 3/2006–5/2012 yielded a malignancy rate of 10.7%, which is lower than previously reported and suggests over-biopsying of lesions at our institution.^{3–11} Malignancy rate was associated with lesion size, washout kinetics and marked background enhancement of the breast parenchyma, confirming the suspicious nature of these findings. In our study, there was no association of malignancy rate with any clinical history characteristics. Pre-operative MRI-guided biopsies of breast lesions visible only on MRI changed surgical management in 28% of women with a new diagnosis of breast cancer. Long-term prospective studies will be needed to assess whether this change in surgical plan is directly related to improved clinical outcomes.

Clinical Practice Points

The malignancy rate of breast lesions undergoing MRI-guided biopsy at our institution 3/2006–5/2012 was 10.7%, which is lower than previously reported and lower than the ACR BI-RADS Atlas 2013 benchmarks,^{3–12} suggesting over-biopsying of lesions at our institution. Among lesions undergoing MRI-guided biopsy, malignancy rate was associated with lesion size, washout kinetics and marked background enhancement, confirming previously published findings.^{2, 11, 27–29} In patients with a new diagnosis of breast cancer undergoing an MRI-guided breast biopsy, the biopsy changed the surgical plan in 28%. This change in surgical plan does not necessarily mean there is an improved clinical outcome in these patients, however, and long-term prospective studies will be needed to assess whether the additional disease detected by preoperative breast MRI is directly related to improved clinical outcomes.

Acknowledgments

We would like to acknowledge Carol B. Thompson, Biostatistics Center, Johns Hopkins Bloomberg School of Public Health for her assistance with the statistical analysis as supported by the National Center for Research Resources and the National Center for Advancing Translational Sciences (NCATS) of the National Institutes of Health through Grant Number 101872.

Funding for this research was partially supported (author KSM) through a Ruth L Kirschstein National Research Service Award (NRSA) Institutional Research Training Grant (T32 NIBIB IT32EB006351).

Author IRK had research grants from Siemens (Munich, Germany), Bracco (Princeton, NJ) and Bayer (Leverkusen, Germany).

References

1. Peters NH, Borel Rinkes IH, Zuithoff NP, et al. Meta-analysis of MR imaging in the diagnosis of breast lesions. *Radiology*. 2008; 246(1):116–124. [PubMed: 18024435]
2. Schnall MD, Blume J, Bluemke DA, et al. Diagnostic architectural and dynamic features at breast MR imaging: multicenter study. *Radiology*. 2006; 238:42–533. [PubMed: 16373758]
3. Mahoney MC. Initial clinical experience with a new MRI vacuum-assisted breast biopsy device. *J Magn Reson Imaging*. 2008; 28:900–9054. [PubMed: 18821610]
4. Orel SG, Rosen M, Mies C, Schnall MD. MR imaging-guided 9-gauge vacuum-assisted core-needle breast biopsy: initial experience. *Radiology*. 2006; 238:54–615. [PubMed: 16304093]
5. Lehman CD, Deperi ER, Peacock S, McDonough MD, Demartini WB, Shook J. Clinical experience with MRI-guided vacuum-assisted breast biopsy. *AJR*. 2005; 184:1782–1787. [PubMed: 15908530]
6. Liberman L, Morris EA, Dershaw DD, Abramson AF, Tan LK. MR imaging of the ipsilateral breast in women with percutaneously proven breast cancer. *AJR Am J Roentgenol*. 2003 Apr; 180(4):901–910. [PubMed: 12646427]
7. Perlet C, Heywang-Kobrunner SH, Heinig A, et al. Magnetic resonance-guided, vacuum-assisted breast biopsy: results from a European multicenter study of 538 lesions. *Cancer*. 2006; 106:982–990. [PubMed: 16456807]
8. Han BK, Schnall MD, Orel SG, Rosen M. Outcome of MRI-guided breast biopsy. *AJR*. 2008; 191:1798–1804. [PubMed: 19020252]
9. Liberman L, Bracero N, Morris E, Thornton C, Dershaw DD. MRI-guided 9-gauge vacuum-assisted breast biopsy: initial clinical experience. *AJR*. 2005; 185:183–193. [PubMed: 15972421]
10. Malhaire C, El Khoury C, Thibault F, et al. Vacuum-assisted biopsies under MR guidance: results of 72 procedures. *Eur Radiol*. 2010; 20:1554e–1562e. [PubMed: 20119729]
11. Rauch GM, Dogan BE, Smith TB, Liu P, Yang WT. Outcome analysis of 9-gauge MRI-guided vacuum-assisted core needle breast biopsies. *AJR Am J Roentgenol*. 2012 Feb; 198(2):292–299. [PubMed: 22268171]
12. Sickles, EA.; D’Orsi, CJ. ACR BI-RADS® Atlas, Breast Imaging Reporting and Data System. Reston, VA: American College of Radiology; 2013. ACR BI-RADS Follow-up and Outcome Monitoring.
13. Elshof ER, Deurloo EE, Pengel KE. A practical approach to manage additional lesions at preoperative breast MRI in patients eligible for breast conserving therapy: results. *Breast Cancer Res Treat*. 2010; 124:707–715. [PubMed: 20652399]
14. Schelfout K, Van Goethem M, Kersschot E, et al. Contrast-enhanced MR imaging of breast lesions and effect on treatment. *Eur J Surg Oncol*. 2004; 30(5):501. [PubMed: 15135477]
15. Bedrosian I, Mick R, Orel SG, et al. Changes in the surgical management of patients with breast carcinoma based on preoperative magnetic resonance imaging. *Cancer*. 2003; 98(3):468. [PubMed: 12879462]
16. Obdeijn IM, Tilanus-Linthorst MM, Spronk S, et al. Preoperative breast MRI can reduce the rate of tumor-positive resection margins and reoperations in patients undergoing breast-conserving surgery. *AJR Am J Roentgenol*. 2013 Feb; 200(2):304–310. [PubMed: 23345350]
17. Menes TS, Zissman S, Golan O, Sperber F, Klausner J, Schneebaum S. Yield of selective magnetic resonance imaging in preoperative workup of newly diagnosed breast cancer patients planned for breast conserving surgery. *Am Surg*. 2012 Apr; 78(4):451–455. [PubMed: 22472404]
18. Morrow M. Magnetic resonance imaging in breast cancer: one step forward, two steps back? *JAMA*. 2004; 292:2779–2780. [PubMed: 15585740]
19. Morrow M, Freedman G. A clinical oncology perspective on the use of breast MR. *Magn Recon Imaging Clin N Am*. 2006; 14:363–378.
20. Sardandelli F. Additional findings at preoperative MRI : a simple golden rule for a complex problem? *Breast Cancer Res Treat*. 2010; 124:717–721. [PubMed: 20803241]
21. El Khouli RH, Macura KJ, Barker PB, Elkady LM, Jacobs MA, Vogel-Claussen J, Bluemke DA. MRI-guided vacuum-assisted breast biopsy: a phantom and patient evaluation of targeting accuracy. *J Magn Reson Imaging*. 2009 Aug; 30(2):424–429. [PubMed: 19629977]

22. Morris, EA.; Comstock, CE.; Lee, CH., et al. ACR BI-RADS® Atlas, Breast Imaging Reporting and Data System. Reston, VA: American College of Radiology; 2013. ACR BI-RADS® Magnetic Resonance Imaging.
23. Liberman L, Morris EA, Dershaw DD, Thornton CM, Van Zee KJ, Tan LK. Fast MRI-guided vacuum- assisted breast biopsy: initial experience. *AJR*. 2003; 181:1283–1293. [PubMed: 14573421]
24. Gebauer B, Bostanjoglo M, Moesta KT, Schneider W, Schlag PM, Felix R. Magnetic resonance-guided biopsy of suspicious breast lesions with a handheld vacuum biopsy device. *Acta Radiol*. 2006; 47:907–913. [PubMed: 17077039]
25. Perretta T, Pistolesi CA, Bolacchi F, Cossu E, Fiaschetti V, Simonetti G. MR imaging-guided 10-gauge vacuum-assisted breast biopsy: histological characterization. *Radiol Med (Torino)*. 2008; 113:830–840. [PubMed: 18633687]
26. Lee JM, Kaplan JB, Murray MP, et al. Underestimation of DCIS at MRI-guided vacuum-assisted breast biopsy. *AJR*. 2007; 189:468–474. [PubMed: 17646475]
27. Nunes LW, Schnall MD, Orel SG. Update of breast MR imaging architectural interpretation model. *Radiology*. 2001; 219:484–494. [PubMed: 11323476]
28. Liberman L, Mason G, Morris EA, Dershaw DD. Does size matter? Positive predictive value of MRI-detected breast lesions as a function of lesion size. *AJR Am J Roentgenol*. 2006 Feb; 186(2): 426–430. [PubMed: 16423948]
29. King V, Brooks JD, Bernstein JL, Reiner AS, Pike MC, Morris EA. Background parenchymal enhancement at breast MR imaging and breast cancer risk. *Radiology*. 2011 Jul; 260(1):50–60. [PubMed: 21493794]

Figure 1. Flowchart of Lesion Outcomes

215 lesions underwent MRI-guided biopsy at our institution between 3/2006 and 5/2012 (200 underwent MRI-guided core biopsy and 15 underwent MRI-guided localization or clip placement with surgical biopsy). The malignancy rate at core biopsy was 8.0%. The malignancy rate of MRI-guided localizations was 20%. The final malignancy rate after surgery was 10.7%.

Figure 2. Box plot demonstrating lesion size among benign and malignant lesions

Larger lesion size was significantly associated with malignant pathology outcome, although there was a considerable overlap of lesion size among benign and malignant lesions.

Figure 3. Change in Surgical Plan as a Result of MRI-Guided Biopsy

19/67 (28%) of patients with a new diagnosis of breast cancer undergoing MRI-guided biopsy had a change in their surgical plan as a result of the biopsy.

(NOTE: figure 3 is intended for color print)

Figure 4. Example of MRI-guided breast biopsy changing the surgical plan in a patient with a new diagnosis of breast cancer

(A) axial subtraction image and (B) axial T1-weighted image with dynamic contrast enhanced kinetics in a 45 year old female with biopsy-proven right breast invasive ductal carcinoma (IDC, white arrows) who planned for lumpectomy prior to breast MRI. MRI demonstrated two suspicious foci in the ipsilateral breast (yellow arrows), up to 8 cm from the known cancer. MRI-guided breast biopsy of the posterior focus yielded IDC, and the patient subsequently underwent a mastectomy.

(NOTE: Figure 4 is intended for color print)

Figure 5. Example of MRI-guided breast biopsy changing the surgical plan in a patient with a new diagnosis of breast cancer

(A) Axial subtraction image in a 52 year old female with biopsy-proven right breast invasive lobular carcinoma (ILC, white arrow). (B) Axial subtraction image and (C) axial T1-weighted with dynamic contrast enhanced kinetics MRI also demonstrated a suspicious mass in the contralateral (left) breast with washout kinetics (orange arrow). The left breast mass underwent MRI-guided breast biopsy, yielding invasive ductal carcinoma (IDC). The patient subsequently underwent bilateral lumpectomies.

(NOTE: Figure 5 is intended for color print)

Table 1

Clinical characteristics of patients who underwent MRI-guided biopsy

characteristic	N	malignant	OR (95% CI)	p-value
indication				
high risk screening ^a	60	3/60 (5%)	NA	NA
extent of disease	115	15/115 (13%)	2.9 (0.8, 10.4)	0.1
follow-up	9	3/9 (33%)	8.1 (1.4, 48.4)	0.02
diagnostic work-up	18	1/18 (6%)	1.1 (0.11, 11.5)	0.93
other	13	1/13 (8%)	1.6 (0.15, 16.6)	0.7
strong family history of breast cancer [*]				
no	135	19/135 (14%)	3.2 (0.73, 14.0)	0.12
yes ^a	41	2/41 (5%)	NA	NA
any family history of breast cancer				
no	79	12/79 (15%)	2.0 (0.82, 5.1)	0.12
yes ^a	112	9/112 (8%)	NA	NA
family history of ovarian cancer				
no	143	13/143 (9%)	0.4 (0.13, 1.22)	0.11
yes ^a	25	5/25 (20%)	NA	NA
history of atypia				
no	154	19/154 (12%)	4.2 (0.53, 33.7)	0.17
yes ^a	31	1/31 (3%)	NA	NA
history of benign biopsy				
no	126	15/126 (12%)	1.35 (0.50, 3.65)	0.55
yes ^a	66	6/66 (9%)	NA	NA
current hormonal treatment				
no	136	17/136 (13%)		(underpowered)
estrogen and/or progesterone	14	1/14 (7%)		
adjuvant hormonal therapy	25	1/25 (4%)		
ethnicity				

characteristic	N	malignant	OR (95% CI)	p-value
caucasian ^a	148	18/148 (12%)	NA	NA
African American	30	1/30 (3%)		
Hispanic	4	2/4 (50%)		
Asian	12	1/12 (8%)	1.66 (0.59, 4.69)	0.34
Indian	2	0/2 (0%)		
Arab	2	1/2 (50%)		
other	15	0/15 (0%)		

compared to reference category (superscript a), accounting for within correlation of within patient lesions

* strong family history was defined as a first degree, premenopausal, female relative or a first degree male relative of any age

Table 2

Pathology of Lesions Undergoing MR-guided Biopsy

pathology	Pathology from MRI-guided Core Biopsy	Pathology from MRI- guided needle localization	Pathology from MRI-guided clip placement with mammographic localization	Final Pathology	
	N	N	N	N	Percent
malignant					
IDC	9	1	0	12	5.6
DCIS	5	1	0	8	3.7
mammary carcinoma	2	0	0	1	.5
infiltrating carcinoma	0	0	0	1	.5
carcinoma	0	0	1	1	.5
total	16/200 (8%)			23/215	10.7
atypical					
ALH	7	2	1	12	6.0
ADH	7	2	1	7	3.3
atypia NOS	2	0	0	3	1.4
atypical vascular proliferation	1	0	0	0	0.0
LCIS	1	0	0	1	.5
ADH and ALH	1	0	0	1	.5
total	19/200 (9.5%)			24/215	11.2
high risk without atypia					
papilloma without atypia	10	0	1	10	4.7
complex sclerosing lesion	5	0	0	4	
micropapilloma	4	0	0	4	1.9
radial scar	1	0	0	1	.5
total	20/200 (10%)			19/215	9.3
benign					
fibrocystic change	63	0	3	65	30.2

pathology	Pathology from MRI-guided Core Biopsy		Pathology from MRI-guided needle localization		Pathology from MRI-guided clip placement with mammographic localization		Final Pathology	
	N	Percent	N	Percent	N	Percent	N	Percent
benign breast tissue	31	14.8	1	0.5	0	0	32	14.8
stromal fibrosis	16	8.4	0	0	2	1	18	8.4
sclerosing adenosis	10	4.7	0	0	0	0	10	4.7
fibroadenoma	9	4.2	0	0	0	0	9	4.2
fibroadenomatoid change	5	2.3	0	0	0	0	5	2.3
PASH	4	1.9	0	0	0	0	4	1.9
fat necrosis	3	1.4	0	0	0	0	3	1.4
nodules of adenosis	1	.5	0	0	0	0	1	.5
chronic inflammation	1	.5	0	0	0	0	1	.5
dense stromal tissue	1	.5	0	0	0	0	1	.5
fat	1	.0	0	0	0	0	0	.0
total	145/200 (72.5%)						148/215	69.4
Total	200		7		9		215	100.0

IDC = invasive ductal carcinoma, DCIS = ductal carcinoma in situ, ALH = atypical lobular hyperplasia, ADH = atypical ductal hyperplasia, NOS = not otherwise specified, LCIS = lobular carcinoma in situ, PASH = pseudoangiomatous stromal hyperplasia

Table 3

Imaging characteristics of MRI findings for which biopsy was recommended

imaging characteristic	N	malignant	OR (95% CI)	p-value*
finding type				
mass ^a	79	9/79 (11%)	NA	NA
nonmass enhancement	96	10/96 (10%)	0.86 (0.25, 3.0)	0.82
focus	40	4/40 (10%)	0.96 (0.28, 3.2)	0.94
shape of mass				
round	20	2/20 (10%)	0.79 (0.14, 4.45)	0.79
oval	17	3/17 (18%)	1.6 (0.30, 7.95)	0.6
lobulated	9	0/9 (0%)	NA	NA
irregular ^a	34	4/34 (12%)	NA	NA
margin of mass				
smooth	30	2/30 (7%)	0.16 (0.026, 0.995)	0.049
irregular	36	3/36 (8%)	0.20 (0.39, 1.073)	0.06
spiculated ^a	13	4/13 (31%)	NA	NA
T2 signal of mass or focus				
low	10	2/10 (20%)	3.6 (0.61, 21.5)	0.16
intermediate	30	6/30 (20%)	3.6 (0.99, 13.4)	0.51
high ^a	79	5/79 (6%)	NA	NA
distribution of nonmass enhancement				
focal	45	5/45 (11%)	2.1 (0.23, 19.7)	0.51
linear ^a	18	1/18 (6%)	NA	NA
segmental	19	2/19 (10%)	2.0 (0.17, 24.1)	0.59
other (regional, multifocal, diffuse)	9	2/9 (22%)	4.8 (0.35, 66.3)	0.24
internal enhancement characteristics of nonmass enhancement				
homogeneous	41	5/41 (12%)	1.25 (0.23, 6.9)	0.8
heterogeneous	11	2/11 (18%)	2.0 (0.25, 15.8)	0.51
stippled/punctate	19	1/19 (5%)	0.5 (0.04, 5.8)	0.58

imaging characteristic	N	malignant	OR (95% CI)	p-value*
clumped ^a	20	2/20 (10%)	NA	NA
dynamic contrast enhancement kinetics				
no color	5	0/5 (0%)	3.1 (1.2, 7.7)	0.02
persistent	28	0/28 (0%)		
plateau	68	7/68 (10%)		
washout ^a	82	15/82 (18%)	NA	NA
new or increased from prior exam				
yes ^a	29	3/29 (10%)	NA	NA
no	13	3/13 (23%)	0.39 (0.07, 2.2)	0.28
background uptake				
minimal	55	8/55 (14%)	0.26 (0.07, 0.89)	0.03
mild	71	3/71 (4%)	0.07 (0.02, 0.03)	<0.001
moderate	73	6/73 (8%)	0.14 (0.04, 0.48)	0.002
marked ^a	15	6/15 (40%)	NA	NA
breast density	NS			
predominantly fatty	9	2/9 (22%)	6.7 (0.77, 58.2)	0.08
scattered fibroglandular densities	61	8/61 (13%)	3.6 (0.72, 17.6)	0.12
heterogeneously dense	96	11/96 (11%)	3.0 (0.64, 14.4)	0.16
extremely dense ^a	49	2/49 (4%)	NA	NA
motion on original MRI				
no	195	21/195 (11%)	1.1 (0.23, 5.2)	0.92
yes ^a	20	2/20 (10%)	NA	NA

* compared to reference category (superscript a), accounting for within correlation of within patient lesions