MR Imaging of the Ipsilateral Breast in Women with Percutaneously Proven Breast Cancer

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OBJECTIVE. The purpose of this study was to review MR imaging findings in the ipsilateral breast in women with percutaneously proven breast cancer.

MATERIALS AND METHODS. Retrospective review was performed of records of 70 consecutive women with percutaneously proven unilateral breast cancer who were considered candidates for breast conservation surgery and who had preoperative MR imaging of the ipsilateral breast. MR images and medical records were reviewed.

RESULTS. MR imaging identified mammographically and clinically occult cancer other than the index lesion in the ipsilateral breast in 19 women (27%), including infiltrating cancer in 11 women (16%) and ductal carcinoma in situ in eight women (11%). These additional sites of cancer were in the same quadrant as the index cancer in 14 women (20%), in a different quadrant in three women (4%), and in both the same and different quadrants in two women (3%). Additional sites of cancer were more likely in women with, rather than in those without, a family history of breast cancer (42% vs 14%, $p < 0.02$) and in women whose index cancer was infiltrating lobular rather than other histologies (55% vs 22%, $p < 0.06$). In 17 women (24%), MR imaging detected ipsilateral lesions that were benign. Changes due to prior percutaneous biopsy were infrequently observed on MR images and included a clip in 12 women (17%) and a small hematoma in two women (3%).

CONCLUSION. MR imaging identified additional sites of ipsilateral cancer in 27% of women with percutaneously proven breast cancer. The yield was highest in women with a family history of breast cancer or infiltrating lobular histology in the index cancer. Change after biopsy was infrequent and did not interfere with the MR imaging interpretation.

More than 250,000 women in the United States will be diagnosed with breast cancer this year, of whom more than half may be candidates for breast-conserving surgery [1]. Patient selection for breast conservation requires preoperative assessment of the extent of disease in the breast. The presence of multiple sites of cancer in different quadrants (multicentric cancer) is a contraindication for breast-conserving surgery [2]. The presence of multiple sites of cancer in the same quadrant (multifocal cancer) is associated with a higher frequency of local recurrence and may require wide excision or preclude breast conservation [3, 4].

Percutaneous biopsy is being increasingly used to diagnose breast cancer [5]. Most women with percutaneously diagnosed breast cancer proceed to definitive therapeutic surgery [5]. For these women, preoperative assessment of the extent of disease depends on percutaneous biopsy histology, physical examination, and preoperative imaging studies [6]. MR imaging has been shown to have high sensitivity in the detection of breast cancer [7], but its usefulness in women with prior percutaneous biopsy has not yet been evaluated. This study was undertaken to determine whether breast MR imaging can identify otherwise occult sites of disease in the ipsilateral breast in women with breast cancer diagnosed by percutaneous biopsy.

Materials and Methods

Women, Mammograms, and Timing of Imaging Studies

Retrospective review was performed of the records of 70 consecutive women with percutaneously proven unilateral breast cancer who met the

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following criteria: mammography and physical examination suggested that cancer was confined to one quadrant of the breast; and the patient was being considered for breast conserving surgery, underwent preoperative MR imaging of the ipsilateral breast after percutaneous biopsy between January 1, 2000, and December 31, 2001, and had subsequent pathologic follow-up available. The protocol for this study was approved by our institutional review board.

These 70 women were of a median age of 51 years (range, 32–78 years). Menopausal status was premenopausal in 36 women (51%) and postmenopausal in 34 (49%). Mammographic parenchymal density as per the Breast Imaging Reporting and Data System lexicon [8] was class 4 (extremely dense) in 16 (23%), class 3 (heterogeneously dense) in 44 (63%), class 2 (scattered fibroglandular densities) in nine (13%), and class 1 (almost entirely fat) in one (1%). The median interval between mammography and MR imaging was 24 days (range, 0–137 days). In 69 (99%) of 70 women, the mammogram was obtained within 3 months of the breast MR imaging. The median interval from percutaneous biopsy to breast MR imaging was 19 days (range, 2–101 days). In 69 (99%) of 70 women, MR imaging was performed within 2 months of percutaneous biopsy.

Breast MR Imaging Technique and Interpretation

Breast MR imaging examinations were performed with a 1.5-T magnet (Signa; General Electric Medical Systems, Milwaukee, WI) using a dedicated surface breast coil. The localizing sequence was followed by a sagittal fat-suppressed T2-weighted sequence (TR/TE, 4000/85). A T1-weighted three-dimensional, fat-suppressed fast spoiled gradient-echo (17/2.4; flip angle, 35°; bandwidth, 31.25 MHz) sequence was then performed before and three times after the bolus IV injection of 0.1 mmol/L of gadopentetate dimeglumine (Magnevist; Berlex, Wayne, NJ) per kilogram of body weight.

Image acquisition started immediately after contrast material injection and saline bolus. Images were obtained sagittally with an acquisition time per volumetric acquisition of less than 2–3 min each. Section thickness was 2–3 mm without gap using a matrix of 256 × 192 and field of view of 18–22 cm. Frequency was in the anteroposterior direction. After the examination, the unenhanced images were subtracted from the first contrast-enhanced images on a pixel-by-pixel basis.

Breast MR images were interpreted per published criteria [9]. During the study period at our institution, more than 1300 clinical breast MR imaging studies were performed and interpreted by six radiologists specializing in breast imaging. For nonpalpable, mammographically occult, MR imaging–detected lesions warranting biopsy, correlative sonography was performed at the discretion of the interpreting radiologist to determine whether the lesion was sonographically visible and therefore amenable to tissue sampling under sonographic guidance. If the lesion was not seen at sonography, MR imaging–guided needle localization for surgical excision was performed with previously described methods [10].

Histologic Analysis of Lumpectomy and Mastectomy Specimens

The outer surface of the intact lumpectomy specimen was inked and sectioned in 3- to 4-mm intervals. When a gross tumor mass was identified, the tumor mass was entirely submitted for microscopic examination, and the tumor size and its relationship to the resection margins were documented. Margin sections and random sections from the most fibrous areas of the remaining breast tissue were also taken. A similar procedure was followed for the submission of mastectomy specimens with the addition of the nipple and random sections from all quadrants.

If a localization wire was present in the lumpectomy or mastectomy specimens in an area other than the index lesion, sections of this area were submitted and comment was made regarding the histologic findings in the tissue around the localizing wire. Specimen radiographs obtained for nonpalpable lesions were examined and correlated with the gross tissue examination. All tissue sections were fixed in 10% neutral formalin, embedded in paraffin, cut at a thickness of 5 μm, and stained with H and E.

Index Cancers

Among 70 index cancers, 49 (70%) were palpable, 19 (27%) were nonpalpable, and two (3%) presented with eczematoid rashes on the nipple and were proven to be Paget's disease. Of 19 nonpalpable cancers, 17 were detected on screening mammography and two on screening sonography. Of 49 palpable cancers, 34 (69%) were seen on the mammogram. The two cases of Paget's disease were mammographically occult.

The median mammographic size of the index cancer was 1.8 cm (range, 0.3–5.0 cm). Sonography, which was performed to assess 56 index cancers, showed a sonographic correlate in 50 (89%), including 43 (93%) of 46 palpable and seven (70%) of 10 nonpalpable index cancers. The median sonographic size of the index cancer was 1.4 cm (range, 0.4–4.0 cm). The median maximal diameter of the index cancer on conventional studies, defined as the larger of the diameters measured on mammography or sonography, was 1.5 cm (range, 0.3–5.0 cm).

The percutaneous biopsy method was sonographically guided 14-gauge automated core biopsy in 36 (51%), stereotactic 11-gauge vacuum-assisted biopsy in 15 (21%), fine-needle aspiration under palpation in nine (13%), core biopsy under palpation in seven (10%), and sonographically guided fine-needle aspiration biopsy in three (4%).

Histology of these 70 index cancers was infiltrating ductal carcinoma in 45 (64%), including 39 with ductal carcinoma in situ (DCIS); infiltrating lobular carcinoma in 11 (16%), including five with DCIS; infiltrating lobular and infiltrating ductal carcinoma in seven (10%), including five with DCIS; and DCIS in seven (10%). Among seven DCIS lesions, the histologic subtype was solid and cribriform (n = 2); solid (n = 1); solid and flat (n = 1); solid, cribriform, micropapillary, and clinging (n = 1); papillary and cribriform (n = 1); and apocrine (n = 1). The nuclear grade was high in five, intermediate in one, and low in one.

Of 70 index cancers, 66 (94%) were visible on MR images obtained after percutaneous biopsy. The four index cancers that were not seen on MR images included one case of Paget's disease; two subcentimeter clusters of calcifications (measuring 0.5 and 0.3 cm, respectively) for which stereotactic biopsy and clip placement had been performed yielding DCIS and infiltrating lobular carcinoma in the former and DCIS in the latter (with residual cancer at surgery in the former but not the latter); and one palpable, mammographically occult, sonographically evident 1.0-cm mass for which sonographically guided core biopsy yielded infiltrating ductal carcinoma and DCIS. In that fourth case, suboptimal fat suppression in the area of the lump limited evaluation of the MR images.

Data Collection and Analysis

Records of the 70 women with percutaneously proven cancer who underwent preoperative MR imaging of the ipsilateral breast were reviewed to determine the frequency of recommending biopsy and biopsy results. The likelihood of detecting otherwise occult cancer at MR imaging was calculated as a function of family history of breast cancer, index cancer size and histology, breast density, and menopausal status.

Breast MR imaging studies were posted on a PACS (picture archiving and communication system) monitor (General Electric Medical Systems) and reviewed by one radiologist who was unaware of the pathologic outcome. The study radiologist was a specialist in breast imaging who had interpreted more than 500 breast MR imaging studies before reviewing these cases. Postbiopsy changes were sought, including hematoma, skin thickening, enhancement of the skin or needle tract, and signal void at the site of a localizing clip. Lesions were classified by the study radiologist in accordance with previously described criteria [9].

MR imaging–detected lesions were considered to be additional sites if they were in a different quadrant than the index cancer, if they were in the same quadrant but were separated from the index cancer by at least 1.0 cm of intervening normal-appearing tissue on MR imaging, or if they were in the same quadrant and contiguous with the index cancer but extended at least 4.0 cm beyond the site of the index cancer. The latter instance was included because of the investigators' hypothesis that wide excision without the information from MR imaging would not have included this area. The quadrant of the lesion was determined with respect to the plane of the nipple (marked with a vitamin E capsule), with the understanding that apparent quadrant location can be affected by positioning for MR imaging.

Biopsy was recommended for 45 MR imaging–detected ipsilateral lesions in 36 women. One of

these lesions was not evident on the day of MR imaging–guided localization and biopsy was canceled. Correlative sonography was performed in 25 lesions and revealed a sonographic correlate in two. None of the lesions was palpable and none had a mammographic correlate. Biopsy method was MR imaging–guided localization in 18, mastectomy in 13, wide excision in 11, sonographically guided localization in one, and sonographically guided core biopsy in one. Mammograms and sonograms were reviewed to assess for correlates to these MR imaging–detected lesions. Pathology records were reviewed to determine histologic findings, including stage of cancers detected [11].

Data were recorded in a spreadsheet (Excel; Microsoft, Redmond, WA) for analysis. Statistical analysis was performed with the chi-square and Fisher's exact tests using statistical software (Epi Info; Centers for Disease Control, Atlanta, GA), with a p value of less than 0.05 considered significant.

Results

MR Imaging Detection of Otherwise Occult Ipsilateral Cancer

MR imaging identified otherwise occult sites of cancer in the ipsilateral breast in 19

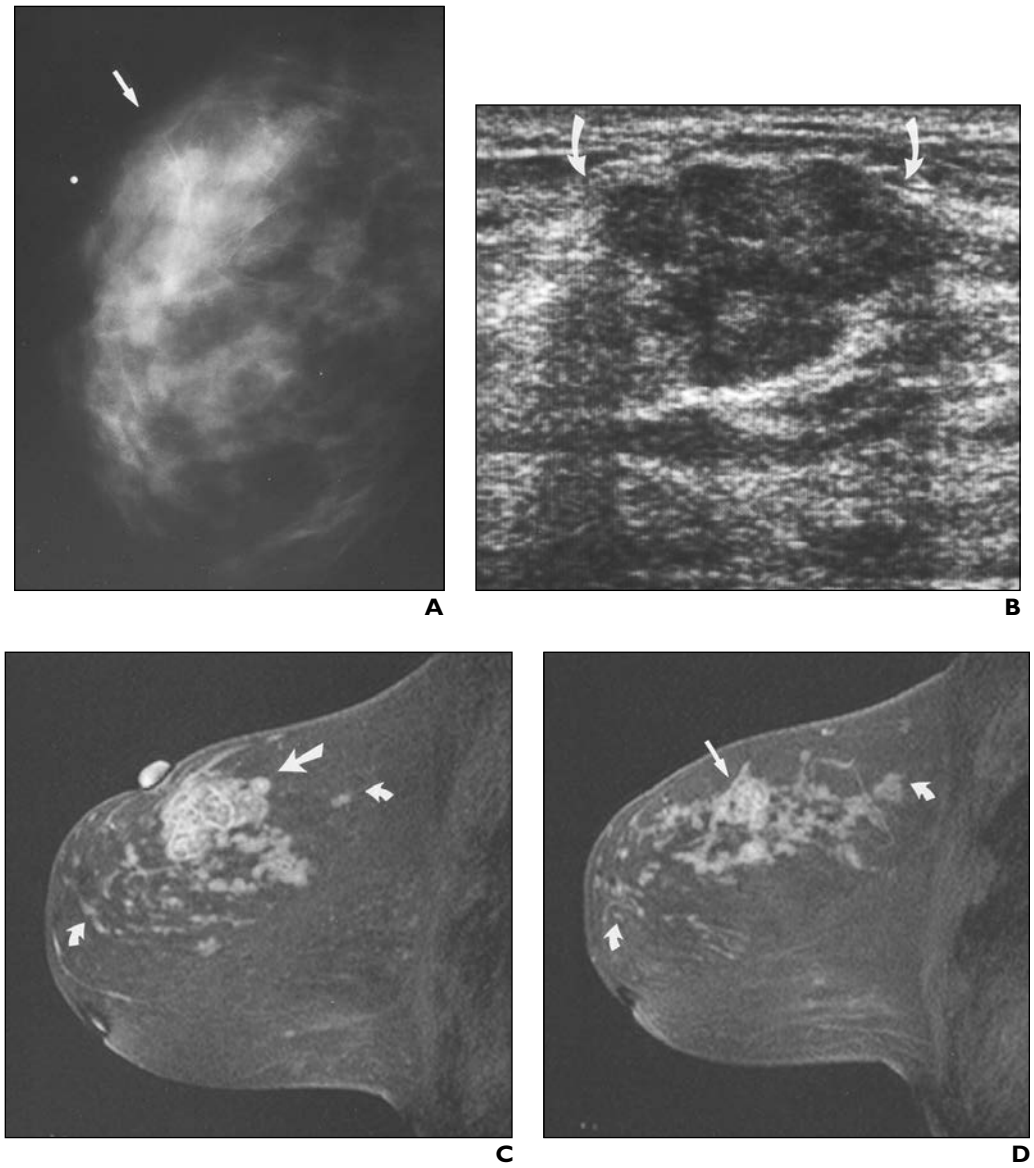

Fig. 1.—34-year-old woman with palpable lump in upper outer quadrant of left breast.
A, Mediolateral oblique left mammogram shows density (*arrow*) in left upper outer quadrant adjacent to radiopaque skin marker denoting palpable lump.
B, Sonogram of left breast shows hypoechoic solid mass (*arrows*) measuring 2 cm that corresponds to palpable lump. Sonographically guided core biopsy yielded infiltrating ductal carcinoma.
C, Sagittal T1-weighted contrast-enhanced MR image of left breast shows irregular multilobulated, rim-enhancing mass (*straight arrow*) corresponding to index cancer adjacent to vitamin E marker denoting palpable lump with extensive adjacent clumped segmental enhancement (*curved arrows*).
D, Sagittal T1-weighted contrast-enhanced MR image of left breast approximately 1 cm medial to **C** shows that segmental clumped enhancement (*curved arrows*) extends anteriorly and posteriorly to index cancer (*straight arrow*), with entire extent of MR imaging abnormality spanning approximately 6.8 cm. Mastectomy revealed infiltrating ductal carcinoma and extensive ductal carcinoma in situ with axillary metastases.

(27%) of 70 women. These cancers were in the same quadrant as the index cancer in 14 women (20%) (Figs. 1 and 2), in a different quadrant in three women (4%) (Fig. 3), and in both the same quadrant and a different quadrant in two women (3%) (Fig. 4). In 14 women with cancers detected in the same quadrant as the index cancer, MR imaging showed that the additional cancers were separate from the index cancer in nine women (median distance, 1.3 cm; range, 1.0–6.1 cm) and contiguous with the index cancer in five women (median extent beyond index cancer, 5.4 cm; range, 5.0–5.5 cm).

The histology of the MR imaging–detected additional sites of cancer in these 19 women was infiltrating in 11 (including seven with DCIS) and DCIS in eight. Subtype of MR imaging–detected infiltrating cancer in 11 women was lobular in five, ductal in five, and mixed in one. Subtype of MR imaging–detected DCIS in eight women was solid (n = 3); solid and cribriform (n = 2); solid, cribriform, and micropapillary (n = 2); and solid, cribriform, and papillary (n = 1). The nuclear grade of DCIS was intermediate in six and high in two. Necrosis was present in six, moderate in five, and minimal in one.

Among 14 women with additional MR imaging–detected sites of cancer in the same quadrant, histology of additional sites was DCIS in seven (50%) and infiltrating cancer in seven (50%) (ductal in four and lobular in three). Among three women with additional MR imaging–detected sites of cancer in different quadrants, the histology of additional sites was infiltrating in all three (lobular in two and mixed lobular and ductal in one). Among two women with additional sites of cancer in both the same and different quadrants, the histology of additional sites was infiltrating ductal in one and DCIS in one. Surgical treatment of these 19 women in whom MR imaging revealed additional sites of cancer was mastectomy in 15 and wide excision in four.

The likelihood of MR imaging detecting otherwise occult sites of cancer in the ipsilateral breast was higher in women with a family history of breast cancer than in women without a family history ($p < 0.02$) and in women whose index cancer was infiltrating lobular as opposed to other histologies ($p < 0.06$) (Table 1). No significant difference in the likelihood of MR imaging detecting otherwise occult sites of ipsilateral cancer was observed as a function of menopausal status, mammographic parenchymal density, or index cancer size (Table 1).

MR Imaging Detection of Benign Lesions

In 17 women (24%), MR imaging led to the detection of additional lesions that were benign (n = 14) or high-risk (n = 3). High-risk lesions included lobular carcinoma in situ, atypical ductal hyperplasia, and atypical ductal hyperplasia and radial scar. The MR imaging–detected lesions in these 17 women were in the same quadrant as the index cancer in seven women and in a different quadrant in 10 women.

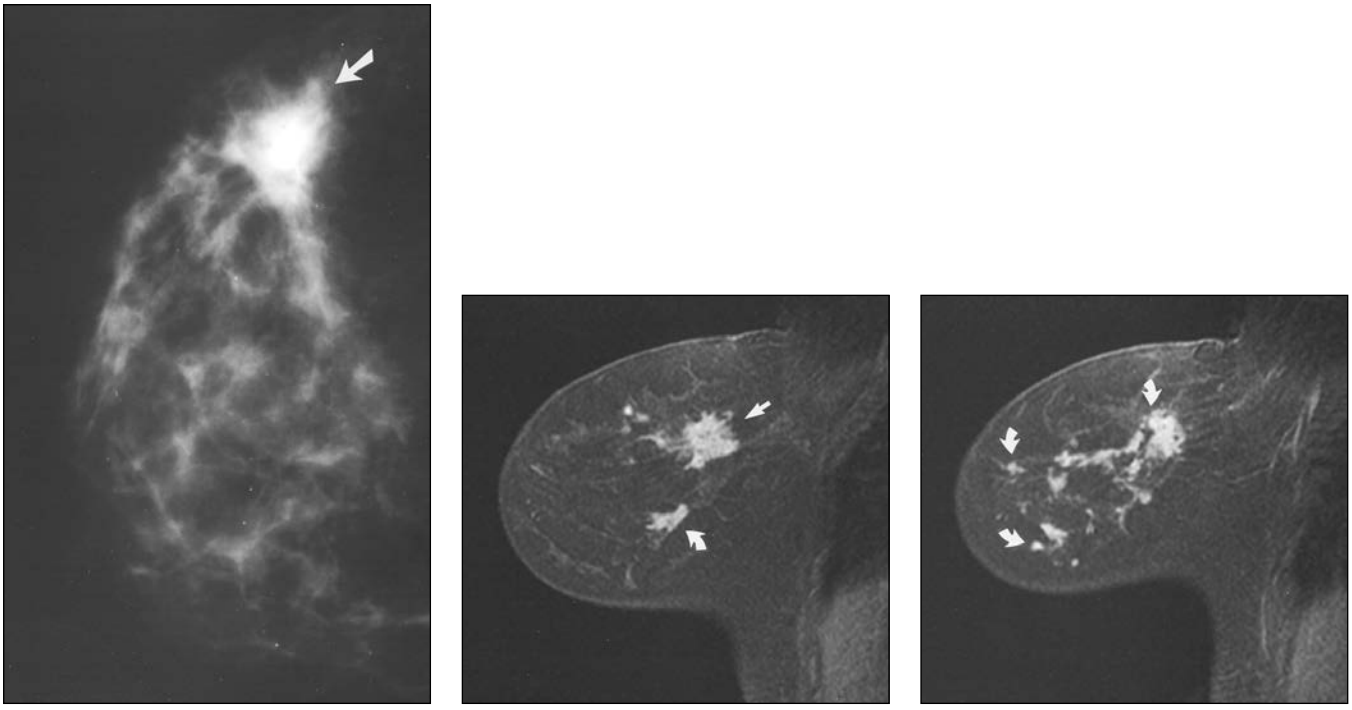

Fig. 2.—42-year-old woman with palpable lump in upper outer quadrant of right breast.
A, Craniocaudal right mammogram shows irregular spiculated mass (*arrow*) in right upper outer quadrant that corresponds to palpable lump. Sonographically guided core biopsy yielded infiltrating ductal carcinoma and ductal carcinoma in situ (DCIS).
B, Sagittal T1-weighted contrast-enhanced MR image of right breast shows irregular spiculated heterogeneously enhancing mass (*straight arrow*) corresponding to index cancer, with additional irregular spiculated mass (*curved arrow*) approximately 1.4 cm inferiorly.
C, Sagittal T1-weighted contrast-enhanced MR image of right breast approximately 6 mm lateral to **B** shows extensive segmental clumped enhancement (*arrows*) spanning approximately 5.5 cm and extending from index cancer toward nipple. Wide surgical excision yielded multifocal infiltrating mammary carcinoma with mixed ductal and lobular features and DCIS, with tumor at resection margins and axillary metastases. Residual infiltrating mammary carcinoma with ductal and lobular features and DCIS was found at mastectomy.

Sixteen of these women underwent excision of these benign lesions, with MR imaging–guided preoperative localization (n = 9), mastectomy (n = 5), wide excision without localization guided by MR imaging findings (n = 1), or sonographically guided preoperative localization (n = 1). One woman was scheduled for MR imaging–guided localization, but the lesion was no longer evident.

Ipsilateral Lesions and Postbiopsy Change

Cancer was identified in 23 (52%) of 44 MR imaging–detected ipsilateral lesions that underwent biopsy, of which nine were DCIS and 14 were infiltrating cancer (ductal in seven, lobular in six, and mixed in one) (Tables 2 and 3). The median lesion size was 1.3 cm (range, 0.5–9.1 cm) for all MR imaging–detected ipsilateral lesions, 1.5 cm (range, 0.5–9.1 cm) for MR imaging–detected lesions yielding cancer, and 1.0 cm (range, 0.5–5.9

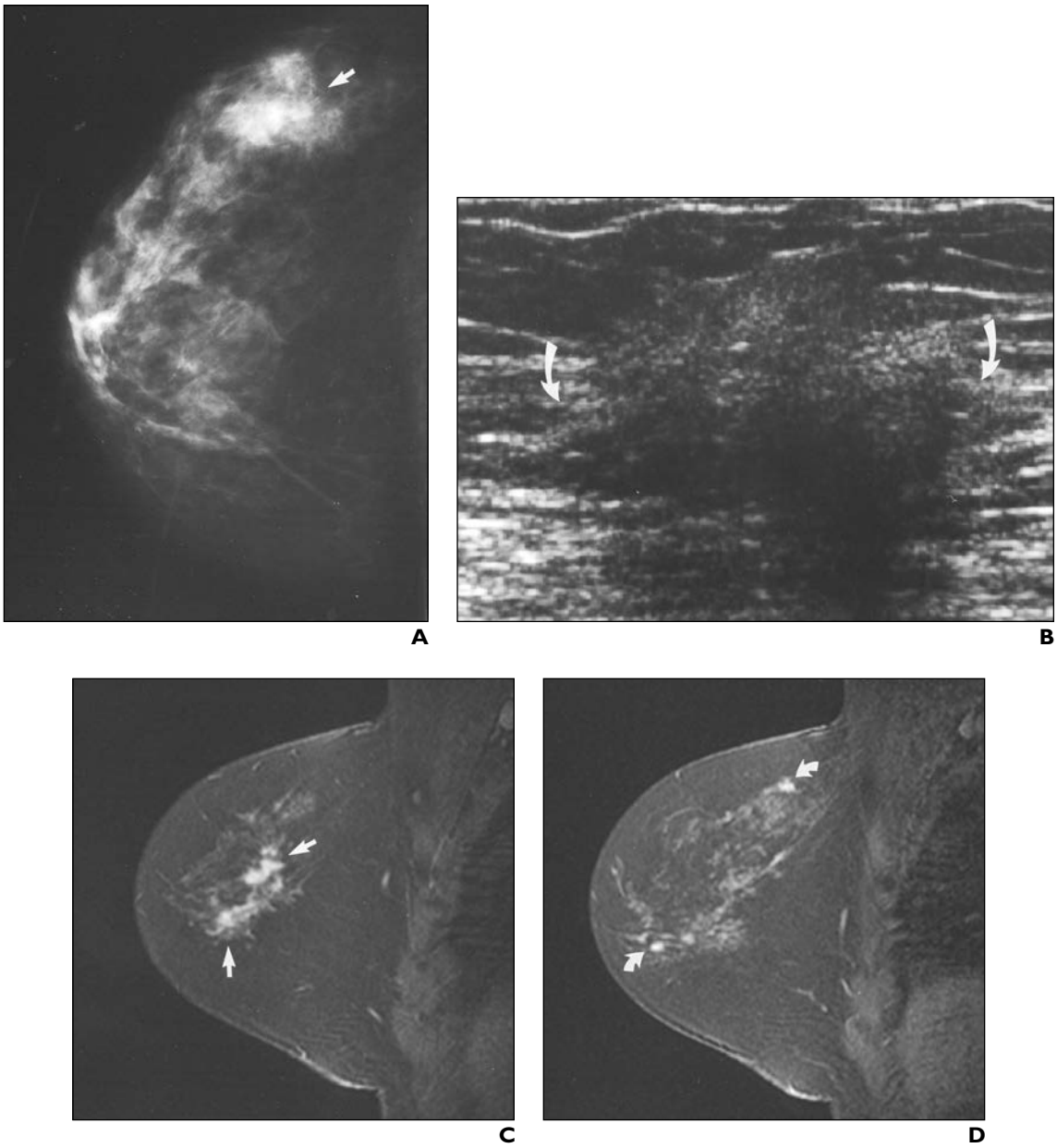

Fig. 3.—78-year-old woman with palpable lump in upper outer quadrant of right breast.
A, Craniocaudal right mammogram shows irregular spiculated mass (*arrow*) that corresponds to palpable lump in right upper outer quadrant.
B, Sonogram of right breast shows irregular hypoechoic solid mass (*arrows*) in upper outer quadrant of right breast that corresponds to palpable and mammographic mass. Sonographically guided core biopsy showed infiltrating lobular carcinoma.
C, Sagittal contrast-enhanced T1-weighted MR image of right breast shows irregular spiculated heterogeneously enhancing mass (*arrows*) in right upper outer quadrant corresponding to index cancer.
D, Sagittal contrast-enhanced T1-weighted MR image of right breast shows additional irregularly shaped, irregularly marginated, heterogeneously enhancing masses (*arrows*) in right upper inner and lower inner quadrants. Mastectomy revealed infiltrating lobular carcinoma in right upper outer, upper inner, and lower inner quadrants and axillary metastases.

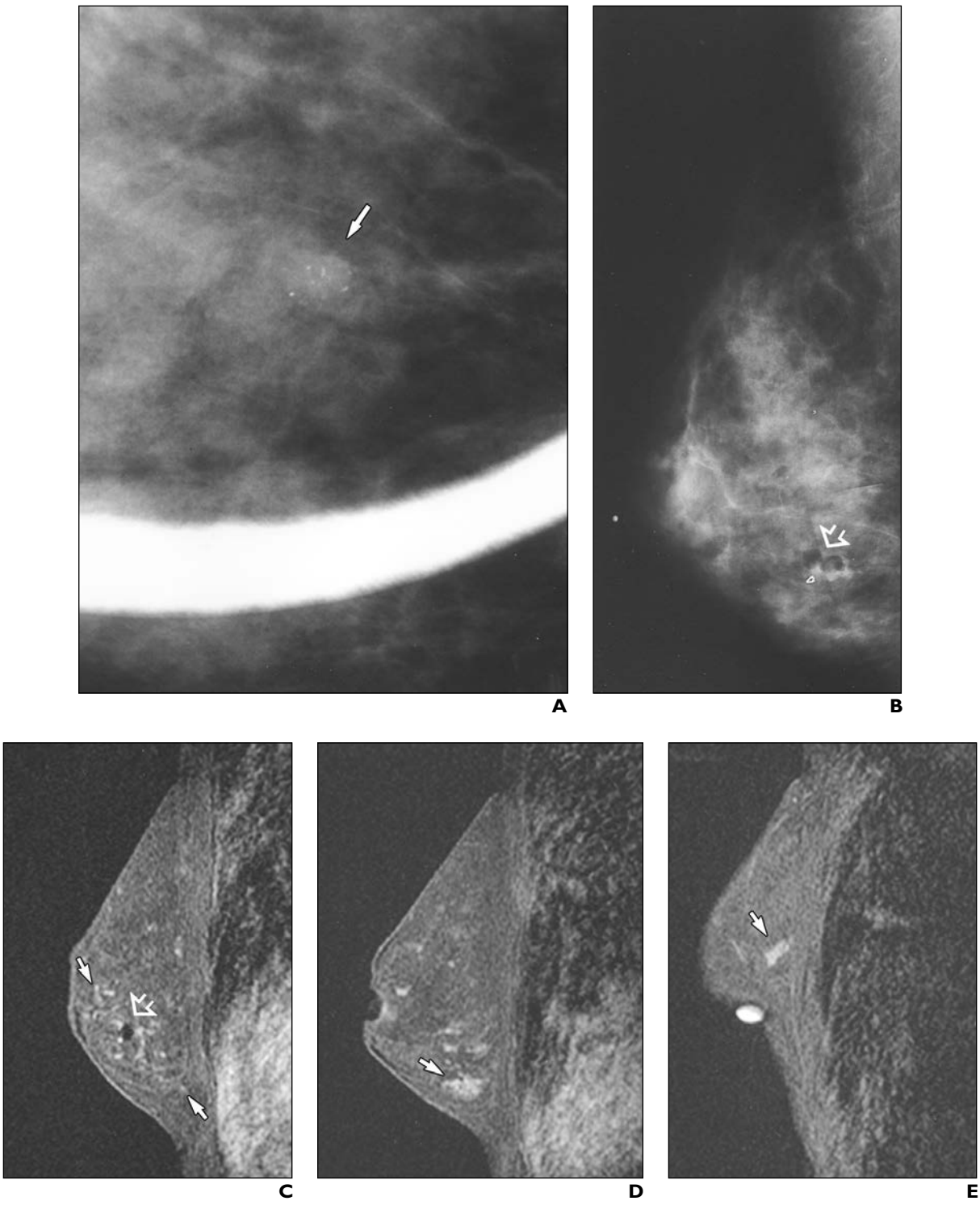

Fig. 4.—47-year-old asymptomatic woman with abnormal findings at mammography.
A, Magnified 90° lateral left mammogram shows 0.4-cm cluster of pleomorphic calcifications (*arrow*) in lower inner quadrant of left breast. Stereotactic biopsy yielded ductal carcinoma in situ (DCIS).
B, Mediolateral oblique left mammogram obtained after stereotactic biopsy shows air and localizing clip (*arrow*) at biopsy site and no residual calcifications.
C, Sagittal T1-weighted contrast-enhanced MR image of left breast shows localizing clip (*open arrow*) evident as signal void and adjacent clumped linear and ductal enhancement (*solid arrows*) in left lower inner quadrant.
D, Sagittal T1-weighted contrast-enhanced MR image of left breast shows separate irregularly shaped, irregularly marginated, heterogeneously enhancing mass (*arrow*) in left breast at 6:00-o'clock position.
E, Sagittal T1-weighted contrast-enhanced MR image of left breast with vitamin E marker placed over skin entry site from stereotactic biopsy shows irregularly shaped, irregularly marginated, heterogeneously enhancing mass (*arrow*) in lower outer quadrant of left breast. MR imaging–guided needle localization was performed of this mass and of mass at 6:00-o'clock position (shown in **D**), and mammographically guided needle localization was performed of clip. All sites yielded DCIS, solid and cribriform type, intermediate nuclear grade. Residual DCIS was found at mastectomy.

cm) for MR imaging–detected lesions that did not yield cancer. Cancer was present in 18 (64%) of 28 lesions in the same quadrant as the index cancer versus five (31%) of 16 lesions in a different quadrant ($p = 0.07$).

Benign findings were present in 17 (39%) of 44 MR imaging–detected ipsilateral lesions, with the dominant findings being benign breast tissue ($n = 4$), sclerosing adenosis ($n = 3$), fibrocystic change ($n = 2$), fibroadenoma ($n = 2$), fibrosis ($n = 2$), ductal hyperplasia ($n = 2$), apocrine metaplasia ($n = 1$), and papilloma ($n = 1$). High-risk findings were present in four (9%) of 44 MR imaging–detected ipsilateral lesions, with the dominant findings being lobular carcinoma in situ ($n = 2$), atypical ductal hyperplasia ($n = 1$), or atypical ductal hyperplasia and radial scar ($n = 1$).

Among MR imaging–detected ipsilateral lesions, features with the highest positive predictive value were segmental enhancement (100% of which were cancer) or clumped enhancement (82%, cancer) for nonmass lesions and spiculated margins (67%, cancer) for masses (Table 2). A trend was seen toward a higher frequency of cancer among lesions with washout than among lesions without washout (86% vs 44%, $p = 0.09$) (Table 3). A washout kinetic pattern was present in six (46%) of 13 invasive cancers, in zero (0%) of nine DCIS lesions, and in one (5%) of 21 benign lesions (Table 3). Cancer was significantly more likely in lesions classified as highly suggestive of malignancy than in lesions classified as suspicious (93% vs 33%, $p < 0.001$) (Table 3).

Postbiopsy change due to prior percutaneous biopsy was seen on MR images in 13 (19%) of 70 women. In 12 women (17%), a localizing clip was evident on MR images as a signal void extending over approximately 6 mm (Fig. 4). In two women (3%) (including one of the 12 who had a localizing clip), small hematomas were observed adjacent to the biopsy site as oblong, nonenhancing fluid collections measuring 1.3 and 1.5 cm that were hyperintense on T2-weighted images. No skin thickening or skin enhancement was observed, and no needle tract could be identified.

Stage and Surgical Treatment

Breast cancer stage, known in 68 of these 70 women, was stage 0 in seven (10%), stage I in 29 (43%), stage II in 29 (43%), and stage III in three (4%). Surgical treatment was breast-conserving surgery in 36 (51%) of 70 women and mastectomy in 34 (49%) of 70 women. Mastectomy was performed in 15 (79%) of 19 women in whom MR imaging detected additional sites of cancer, in five (29%) of 17 women in whom MR imaging detected lesions that proved to be benign, and in 14 (41%) of 34 women in whom MR imaging showed no additional ipsilateral lesions. Women were significantly more likely to have a mastectomy if MR imaging revealed additional sites of cancer than if it did not (15/19 = 79% vs 19/51 = 37%; $p < 0.005$).

TABLE 1 Frequency of MR Imaging Detection of Otherwise Occult Ipsilateral Cancer Versus Various Parameters

Parameter	Frequency (%) of Detection	*p*
Family history of breast cancer		
Yes	14/33 (42)	<0.02
No	5/37 (14)	
Histology of index cancer		
Infiltrating lobular carcinoma	6/11 (55)	<0.06[a]
Infiltrating ductal carcinoma	11/45 (24)	
Infiltrating ductal and infiltrating lobular carcinoma	0/7 (0)	
Ductal carcinoma in situ	2/7 (29)	
Menopausal status		
Premenopausal	13/36 (36)	0.14
Postmenopausal	6/34 (18)	
Breast density pattern		
4 (extremely dense)	5/16 (31)	0.7[b]
3 (heterogeneously dense)	12/44 (27)	
2 (scattered fibroglandular densities)	2/9 (22)	
1 (almost entirely fat)	0/1 (0)	
Size of index cancer[c]		
≥2.0 cm	7/26 (27)	1.0
<2.0 cm	9/39 (23)	

[a] For comparison of infiltrating lobular versus other histologies of index cancer.

[b] For comparison of classes 4 and 3 versus classes 2 and 1.

[c] For 65 index cancers in which size could be measured on mammography, sonography, or both.

Discussion

Women with one area of proven breast cancer may harbor additional sites of cancer in the ipsilateral breast. Pathologic analyses of mastectomy specimens have shown sites of cancer other than the index lesion in 20–63% [12–19] (Table 4). Of these additional sites of cancer, 19–67% were invasive [13–15, 17–19]. In 20–47% of mastectomy specimens, additional sites of cancer were present in quadrants other than that of the index tumor [12–15, 17–19] (Table 4). Among women who underwent mastectomy for DCIS, a multifocal distribution with gaps larger than 1 cm was present in 8% [20], and DCIS involved more than one quadrant in 23–47% [20, 21]; the likelihood of cancer outside the index quadrant was higher in women with DCIS measuring 2.5 cm or larger [14].

In previous studies of women with invasive breast cancer who underwent breast-conserving surgery, local recurrence rates at the 15-year follow-up were 36% for women who did not receive radiation and 12% for women who received radiation [22]. In previous studies of women with DCIS who had breast conservation, local recurrence rates at the 8-year follow-up were 31% for women who did not receive radiation and 13% for women who received radiation [23]. The greater than 30% rates of local recurrence in women who did not receive radiation are within the 20–63% range expected on the basis of the frequency of cancer at additional sites in the breast in the pathology studies [12–14, 17–19]. That the local recurrence rates are lower in women who receive radiation therapy indicates that radiation destroys or retards the growth of some of these sites of disease. Preoperative identification of additional sites of cancer may allow their removal and could potentially lower the frequency of local recurrence.

In our study of women with percutaneously diagnosed breast cancer who were considering breast conservation, MR imaging identified additional sites of cancer in the ipsilateral

TABLE 2 MR Imaging Findings in 44 MR Imaging–Detected Ipsilateral Lesions That Underwent Biopsy: Frequency and Positive Predictive Value

Finding	No. (%)[a] of Lesions	No. (%)[b] of Cancers	Cancer Histology: No. (%)	
			Invasive[c]	DCIS[d]
Masses				
Margins				
Spiculated	3 (7)	2 (67)	2 (100)	0 (0)
Irregular	25 (57)	12 (48)	7 (58)	5 (42)
Smooth	2 (5)	0 (0)	0 (0)	0 (0)
Shape				
Irregular	25 (57)	14 (56)	9 (64)	5 (36)
Lobular	4 (9)	0 (0)	0 (0)	0 (0)
Round	1 (2)	0 (0)	0 (0)	0 (0)
Enhancement				
Heterogeneous	29 (66)	14 (48)	9 (64)	5 (36)
Rim	1 (2)	0 (0)	0 (0)	0 (0)
All masses	30 (68)	14 (47)	9 (64)	5 (36)
Nonmasses[e]				
Ductal	4 (9)	1 (25)	0 (0)	1 (100)
Segmental	3 (7)	3 (100)	1 (33)	2 (67)
Regional	6 (14)	4 (67)	3 (75)	1 (25)
Diffuse	1 (2)	1 (100)	1 (100)	0 (0)
All nonmasses	14 (32)	9 (64)	5 (56)	4 (44)
All lesions	44 (100)	23 (52)	14 (61)	9 (39)

Note.—DCIS = ductal carcinoma in situ.

[a] Proportion of 44 MR imaging–detected lesions that had features indicated.

[b] Proportion of lesions with features indicated that were cancer.

[c] Proportion of cancers with features indicated that were invasive.

[d] Proportion of cancers with features indicated that were DCIS.

[e] Eleven nonmass lesions had clumped enhancement, of which nine (82%) were cancer. Three nonmass lesions that did not have clumped enhancement were ductal lesions with irregular enhancement; all three were benign.

TABLE 3 Kinetic Features, T2 Signal Intensity, and Level of Suspicion in 44 MR Imaging–Detected Ipsilateral Lesions That Underwent Biopsy: Frequency and Positive Predictive Value

Finding	No. (%)[a] of Lesions	No. (%)[b] of Cancers	Cancer Histology: No. (%)	
			Invasive[c]	DCIS[d]
Kinetic features (n = 43)[e]				
Washout	7 (16)	6 (86)	6 (100)	0 (0)
Plateau	35 (81)	16 (46)	7 (44)	9 (56)
Progressive	1 (2)	0 (0)	0 (0)	0 (0)
T2 signal intensity (n = 44)				
Isointense	43 (98)	22 (51)	13 (59)	9 (41)
Hyperintense	1 (2)	1 (100)	1 (100)	0 (0)
Level of suspicion (n = 44)				
Category 4 (suspicious)[f]	30 (68)	10 (33)	6 (60)	4 (40)
Category 5 (highly suggestive)[f]	14 (32)	13 (93)	8 (62)	5 (38)

Note.—DCIS = ductal carcinoma in situ.

[a] Proportion of 44 MR imaging–detected lesions that had features indicated.

[b] Proportion of lesions with features indicated that were cancer.

[c] Proportion of cancers with features indicated that were invasive.

[d] Proportion of cancers with features indicated that were DCIS.

[e] Visually assessed on contrast-enhanced images. Data refer to 43 lesions in which at least two contrast-enhanced image acquisitions were available.

[f] Breast Imaging and Reporting Data System [8].

breast in 27%. The 27% frequency is within the 20–63% range of frequencies of additional sites of cancer reported in previous pathologic analyses of mastectomy specimens [12–19] (Table 4). The 27% frequency with which MR imaging detected additional sites of cancer in the ipsilateral breast is also consistent with prior studies of breast MR imaging in women with proven breast cancer [24–31] (Table 5). In those studies, MR imaging identified additional sites of ipsilateral cancer that were not identified on mammography or at physical examination in 6–34% of women [24–31].

In women with additional ipsilateral sites of cancer detected on MR imaging in our study, approximately three quarters (74%) had additional sites only in the quadrant of the index cancer and one quarter (26%) had additional sites of cancer in other quadrants. This distribution mirrors the distribution of local recurrences at the 15-year follow-up of women with invasive breast cancer who had breast conservation, in which 75% were found in the same quadrant as the index lesion and 25% in different quadrants [22]. In other studies of MR imaging, the distribution of MR imaging–detected additional sites of cancer has varied, with 10–89% in the same quadrant as the index tumor [24–31] (Table 5). The differences in distribution may reflect differences in MR imaging technique, interpretation, or patient populations, and should be investigated in future work.

We found subsets of women in whom breast MR imaging was most likely to identify otherwise occult sites of ipsilateral cancer. The frequency of ipsilateral cancer was significantly higher in women with a family history of breast cancer than in women without such history (42% vs 14%, $p < 0.02$). This finding is consistent with the prior pathology literature: in mastectomy specimens of cancers smaller than 2 cm, Rosen et al. [13] found additional sites of cancer in 40% of women with a positive family history versus 23% of women with no family history of breast cancer [13]. We also found a trend toward a higher frequency of additional cancer in women whose index cancer was infiltrating lobular rather than other histologies (55% vs 22%, $p < 0.06$). This finding is also consistent with the findings of Rosen et al. [13], who noted additional sites of ipsilateral cancer in the mastectomy specimens in 50% of women with infiltrating lobular histology in the index cancer versus 31% of women with other histologies. Breast density did not significantly affect the likelihood of MR imaging detecting otherwise occult cancer in our study, but 86% of our women had heterogeneously dense or extremely dense breasts.

The positive predictive value of biopsy in MR imaging–detected ipsilateral lesions in women with percutaneously proven breast cancer was high (52%). This 52% positive predictive value is within the 18–64% range of positive predictive values for biopsy on the basis of the MR imaging findings in high-risk women [32–36] and higher than the 20–40% range of positive predictive values for mammographically guided needle localization and surgical excision in the general population [37]. We found a trend toward a higher frequency of cancer occurred among lesions in the same quadrant as the index cancer rather than different quadrants (64% vs 31%, $p = 0.07$). This finding is consistent with the prior results of breast MR imaging in women with breast cancer reported by Bedrosian et al. [31], who found cancer in 75% of MR imaging–detected lesions in the same quadrant as the index cancer versus 47% of lesions in different quadrants.

Although our data confirm the high positive predictive value of certain MR imaging lesion features such as spiculated mass margins, segmental nonmass enhancement, clumped nonmass enhancement, and a washout kinetic pattern [9], most MR imaging–detected lesions in our study had nonspecific findings, which suggests the highly variable pattern of breast cancer on MR imaging and reinforces the necessity of biopsy to determine lesion histology. In none of our patients were changes related to the prior needle biopsy confused with possible malignancy. Postbiopsy change was infrequent on MR images obtained after percutaneous biopsy, with small hematomas present in 3% and no enhancement of the needle tract. The localizing clip, placed after percutaneous biopsy in 17% of our women, did not interfere with interpretation of the MR images.

Breast sonography, which was not performed in almost half of our women, can detect additional ipsilateral disease in women with breast cancer [38, 39]. Breast MR imaging, however, may have several advantages over sonography in the assessment of extent of disease. Studies of high-risk women who had mammography, sonography, and MR imaging reported sensitivities of 86–100% for MR imaging versus 33–43% for sonography [32, 34]. MR imaging is more sensitive than sonography in the detection of DCIS [38]. The 18–64% positive predictive value of biopsy in studies of MR imaging screening [32–36] is significantly higher than the 7–14% positive predictive value of biopsy in studies of screening sonography [32, 40–42]. Breast sonography does retain some advantages, however: it

TABLE 4 Pathologic Analysis of Ipsilateral Breast in Mastectomy Studies

Investigators	No. of Mastectomy Specimens	No.[a] (%) with Additional Sites of Ipsilateral Cancer	No.[b] (%) in Same Quadrant	No.[b] (%) in Different Quadrant
Qualheim and Gall [12][c]	157	85 (54)	27 (17)	58 (37)
Rosen et al. [13][d]	203	65 (32)	NA	65 (32)
Lagios [14][e]	84	17 (20)	NA	17 (20)
Schwartz et al. [15][f]	43	16 (37)	NA	16 (37)
Egan [16][g]	116	71 (61)	NS	NS
Holland et al. [17][h]	282	177 (63)	56 (20)	121 (43)
Anastassiades et al. [18][i]	365	169 (46)	NA	169 (46)
Vaidya et al. [19][k]	30	19 (63)	5 (17)	14 (47)

Note.—Many of these studies included cases of lobular carcinoma in situ (LCIS) among index lesions, additional sites of cancer, or both. Currently, LCIS is not considered cancer but rather a risk factor for subsequent development of cancer. Therefore, in calculating proportion of mastectomies in which additional sites of cancer were found for this table, attempt was made to remove cases in which index cancer was LCIS from denominator and cases in which additional sites were LCIS from numerator. NA = not applicable, NS = not stated.

[a] Mastectomies in which cancer was found in areas other than index cancer, expressed as percentage of all mastectomies.

[b] Mastectomies with additional sites of cancer in quadrant indicated, expressed as percentage of all mastectomies.

[c] Number of cases of LCIS not stated, but authors state, "The few examples of lobular carcinoma in situ appearing in this series were obviously manifestations of independency of origin."

[d] All index cancers were invasive. Number of additional sites that were LCIS was not stated. Additional sites of cancer were found in 26% (26/100) of mastectomies with index cancers <2 cm and in 38% (39/103) of mastectomies with index cancers ≥ 2 cm.

[e] Excludes one case in which index cancer was LCIS and one case in which additional site was LCIS.

[f] Excludes one case in which index cancer was LCIS and three cases in which additional sites were LCIS.

[g] Excludes one case in which index cancer was unicentric LCIS and one case in which index lesion and additional sites were LCIS.

[h] All index cancers were invasive. Number of additional sites that were LCIS was not stated. Analysis was with respect to distance from index cancer rather than quadrant. Of 177 additional sites of cancer, distance from index cancer was ≤ 2 cm in 56 and > 2 cm in 121.

[i] Excludes one case in which index cancer and additional sites were LCIS and 17 cases in which additional sites were LCIS.

[k] All index cancers were invasive. Includes one case in which index cancer was infiltrating lobular and additional site was LCIS.

TABLE 5 MR Imaging of Ipsilateral Breast in Women with Breast Cancer

Investigators	No. of Women	No.[a] (%) with Additional MR Imaging–Detected Ipsilateral Cancer	No.[b] (%) in Same Quadrant	No.[b] (%) in Different Quadrant
Harms et al. [24]	29[c]	10 (34)	3 (10)	7 (24)
Orel et al. [25]	64	13 (20)	NS[d]	NS[d]
Boetes et al. [26]	61[c]	9 (15)	8 (13)	1 (2)
Mumtaz et al. [27]	92[c]	10 (11)	1 (1)	9 (10)
Fischer et al. [28]	336	54 (16)	30 (9)	24 (7)
Drew et al. [29]	178	41 (23)	15 (8)	26 (15)
Esserman et al. [30]	58[c]	6 (10)	NS	NS
Bedrosian et al. [31]	231	14 (6)	6 (3)	8 (3)
This study	70	19 (27)	14 (20)	5 (7)[e]

Note.—NS = not stated.

[a] Women with MR imaging–detected sites of cancer other than index lesion, as percentage of all women in study.

[b] Women with MR imaging–detected sites of cancer in quadrant indicated, as percentage of all women in study.

[c] Number of breasts rather than number of women.

[d] Quadrant of additional sites of MR imaging–detected cancer, given for 11 of 13 women, was same as quadrant of index cancer in seven and different in four. Among 13 women with additional sites of cancer detected at MR imaging, nine were considered to have multifocal disease (defined in study as distinct at gross examination or having separate, dispersed, microscopic foci) and four were considered to have diffuse disease (defined in study as several lesions that were ill-defined at gross examination with large areas of dispersed intraductal and infiltrating carcinoma).

[e] Includes two women with additional MR imaging–detected sites of cancer in both same quadrant and different quadrant.

is inexpensive, fast, widely available, and provides ready access for biopsy procedures.

Although breast MR imaging can detect additional sites of cancer in the ipsilateral breast, several caveats should be remembered. Breast MR imaging is an expensive examination, with no standardization of technique or interpretation, and it is not feasible in some women such as those with pacemakers, aneurysm clips, or claustrophobia. Breast MR imaging should be reserved for settings with the capability for performing biopsy of lesions detected only on MR imaging. Breast MR imaging has limited specificity: in our study, 24% of women were referred for biopsy as a result of MR imaging detection of lesions that were not cancer. Finally, the biologic significance of these additional MR imaging–detected sites of cancer is not yet known. In our study, women with additional sites of cancer detected at MR imaging were significantly more likely to undergo mastectomy; it is likely, however, that some of these sites may have been biologically indolent or controlled by radiation.

In conclusion, breast MR imaging identified additional sites of cancer in 27% of women with percutaneously proven breast cancer. The likelihood of identifying additional sites of cancer was highest in women with a family history of breast cancer and in women with lobular histology in the index cancer. The frequency and distribution of MR imaging–detected sites of cancer in our study mirror the frequency and distribution of local recurrences in women treated with breast conservation without radiation. Additional work, including refinement of methods for MR imaging–guided core biopsy, analysis of the use of MR imaging in assessing the margins of surgical resection, evaluations of cost-effectiveness, and long-term follow-up will be necessary to determine the role of breast MR imaging in the preoperative assessment of women with proven breast cancer.

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