

Enhancing Nonmass Lesions in the Breast: Evaluation with Proton (^1H) MR Spectroscopy¹

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Purpose:

To prospectively evaluate the sensitivity and specificity of proton (hydrogen 1 [^1H]) magnetic resonance (MR) spectroscopy for diagnosing malignant enhancing nonmass lesions identified at breast MR imaging, with histologic examination as the reference standard.

Materials and Methods:

In this HIPAA-compliant, institutional review board–approved study, in which all participants gave written informed consent, proton (^1H) MR spectroscopy of the breast was performed in suspicious or biopsy-proved malignant lesions that were 1 cm or larger at MR imaging. Single-voxel proton (^1H) MR spectroscopic data were collected. MR spectroscopic findings were defined as positive if the signal-to-noise ratio of the choline resonance peak was 2 or greater and as negative in all other cases. MR spectroscopic results were then compared with histologic findings, and statistical analysis was performed.

Results:

In 32 women (median age, 48.5 years [range, 20–63 years]) with enhancing nonmass lesions, the median lesion size at MR imaging was 2.8 cm (range, 1.2–9.0 cm). At histologic analysis, 12 (37%) of 32 lesions were malignant and 20 (63%) were benign. Positive choline findings were present in 15 of 32 lesions, including all 12 (100%) cancers and three (15%) of 20 benign lesions, giving proton (^1H) MR spectroscopy a sensitivity of 100% (95% confidence interval [CI]: 74%, 100%) and a specificity of 85% (95% CI: 62%, 97%) for detection of enhancing nonmass lesions. For 25 lesions with unknown histologic features, proton (^1H) MR spectroscopy would have significantly ($P < .01$) increased the positive predictive value of biopsy from 20% to 63%. If biopsy had been performed for only those lesions with positive choline findings at proton (^1H) MR spectroscopy, biopsy might have been avoided for 17 (68%) of 25 lesions, and no cancers would have been missed.

Conclusion:

Proton (^1H) MR spectroscopy had 100% sensitivity and 85% specificity for the detection of malignancy in enhancing nonmass lesions.

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Although magnetic resonance (MR) imaging can help to identify breast cancers that cannot be detected with mammography or physical examination, there is substantial overlap in the morphologic and kinetic patterns of benign and malignant lesions. Biopsy is often necessary for histologic diagnosis. Breast MR imaging is particularly challenging in premenopausal women, in whom hormonal cyclical changes frequently pose a diagnostic dilemma that may result in recommendations for biopsy (1). Additionally, background enhancement may be seen in both pre- and postmenopausal patients, regardless of hormonal status; this enhancement may also be erroneously interpreted as suspicious, prompting biopsy.

Most MR imaging enhancing lesions referred for biopsy are described as mass or nonmass enhancement. Nonmass enhancement, defined as “enhancement of an area that is not a mass,” may extend over large or small regions, with internal enhancement that is discrete from normal enhancing breast parenchyma (2). Nonmass enhancement has been described with benign hormonal changes and other benign entities but may also occur in malignancies (3,4). Biopsy is often necessary to distinguish benign enhancing nonmass lesions from cancer.

Proton MR spectroscopy has been suggested as an adjunct to breast MR imaging in the distinction of benign from malignant lesions. The diagnostic value of proton (hydrogen 1 [¹H]) MR spectroscopy is typically based on the detection of elevated levels of choline compounds, which are a marker of active tumor (5). Investigators in prior studies (6–15) of breast proton (¹H) MR spec-

troscopy performed with 1.5-T MR units have reported sensitivities of 70%–100% and specificities of 67%–100% (Table). Few data, however, address the application of proton (¹H) MR spectroscopy to enhancing nonmass breast lesions. Thus, the purpose of our study was to prospectively evaluate the sensitivity and specificity of proton (¹H) MR spectroscopy for diagnosing malignant enhancing nonmass lesions identified at breast MR imaging, with histologic examination as the reference standard.

Materials and Methods

Patients

This Health Insurance Portability and Accountability Act–compliant study was approved by the institutional review board of Memorial Sloan-Kettering Cancer Center. All women who participated gave written informed consent. Participants meeting study inclusion criteria were 18 years of age or older and were either undergoing diagnostic MR imaging for a biopsy-proved breast lesion that measured 1 cm or larger or undergoing MR imaging–guided biopsy or needle localization for a breast lesion that measured 1 cm or larger on MR images. Exclusion criteria were inability to undergo or complete the MR imaging examination, neoadjuvant chemotherapy for breast cancer, and presence of a breast hematoma (from recent surgery or biopsy) adjacent to the suspicious lesion.

Patients from a consecutive pool of patients who were undergoing diagnostic MR imaging or MR imaging–guided biopsy or needle localization were prospectively included. To identify patients with lesions measuring 1 cm or larger, a radiologist (L.B.) with 6 years of experience as a breast imaging specialist reviewed, on a weekly basis, the diagnostic MR images of patients who were

scheduled to undergo MR imaging–guided procedures. This radiologist also reviewed, again on a weekly basis, a separate list of patients undergoing diagnostic MR imaging of the breast to identify those with a biopsy-proved lesion measuring 1 cm or larger. The appropriate clinician was subsequently informed about eligible patients before the day of the study so that the clinician could inform the patient. Medical records were reviewed, and the patient’s age and indications for the initial breast MR examination were recorded.

Single-Voxel Proton (¹H) MR spectroscopy

Single-voxel (ie, one rectangular volume of interest) proton (¹H) MR spectroscopic data were acquired by using a 1.5-T whole-body MR imager (LX or Excite; GE Medical Systems, Milwaukee, Wis). The body coil was used as the transmitter, and a dedicated four-channel breast coil or seven-channel phased-array breast coil (MR Imaging Devices, Waukesha, Wis) was used as the receiver. All four coils were turned on for signal reception when the four-channel coil was used, whereas only the four coils on the side of the examined breast were turned on when the seven-channel coil was used. An intravenous contrast agent, gadopentetate dimeglumine (Magnevist; Nihon Schering, Osaka, Japan),

Advance in Knowledge

- The use of breast MR spectroscopy in conjunction with MR imaging significantly ($P < .01$) increases the positive predictive value of MR imaging for detection of nonmass enhancing lesions and decreases the number of benign-result biopsies recommended according to MR imaging findings.

Implication for Patient Care

- Breast MR spectroscopy appears to help eliminate at least some of the false-positive-result biopsy recommendations generated with breast MR imaging.

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Abbreviations:

BI-RADS = Breast Imaging Reporting and Data System
 CI = confidence interval
 DCIS = ductal carcinoma in situ
 SNR = signal-to-noise ratio

Author contributions:

Guarantor of integrity of entire study, L.B.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, L.B., E.A.M., E.C., M.C.C., L.L.; clinical studies, L.B., S.B.T., D.D.D., W.H., E.C., M.C.C.; statistical analysis, M.C.C.; and manuscript editing, L.B., S.B.T., E.A.M., D.D.D., W.H., E.C., L.L.

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was administered by means of manual injection (total dose, 0.1 mmol per kilogram of body weight) and followed by a 20-mL saline flush. Pre- or postcontrast sagittal T1-weighted MR images with fat saturation (acquired with three-dimensional spoiled gradient-recalled acquisition in the steady state; 35° flip angle, 18.8/4.2 [repetition time msec/echo time msec], 3.0-mm section thickness, 18–20-cm field of view, and 256 × 192 matrix) were used as scout images for placement of the rectangular proton (^1H) MR spectroscopy voxel. Voxel placement was performed by one of two physicists (S.B.T. or W.H., with 3 and 6 years' experience in proton (^1H) MR spectroscopy of the breast, respectively) to encompass the lesion. Voxel sizes ranged from 1.2 to 9.0 cm³ (median, 2.8 cm³). The proton spectrum was collected with a point-resolved spectroscopy sequence (2000/135; 128 signals acquired).

With automatic shimming on the unsuppressed water signal, less than 20 Hz of the full width at half maximum usually was achieved. If the full width at half maximum was more than 20 Hz after automatic shimming, quick manual shimming (by S.B.T. or W.H.) was performed to adjust the full width at half maximum to less than 20 Hz.

The total imaging time, including the time for preimaging adjustment for

shimming and water suppression, was initially about 20 minutes. The time had decreased to 10 minutes, owing to gained experience, by the end of patient accrual.

Data Processing

The acquired raw proton (^1H) MR spectroscopic data were transferred to a computer workstation and were processed by using a software program (SAGE/IDL; GE Medical Systems) with a 5-Hz line-broadening Fourier transformation and phase and baseline corrections. After Fourier transformation and phase and baseline corrections, the multichannel data sets were added by means of weighted averaging to generate the final spectrum. The weighing factor for the spectrum from each coil channel was the peak height of the water resonance in the corresponding reference water-unsuppressed spectrum (16 signals acquired) from the same channel. A choline resonance peak was searched for at a frequency of 3.23 ppm. The baseline was corrected by using a cubic spline method, which was performed by choosing data points in the frequency ranges of 3.5–4.0 and 2.5–3.0 ppm and setting these data points to zero. The signal-to-noise ratio (SNR) of the choline peak was calculated as the ratio of choline peak amplitude to noise amplitude, which was

measured in the flat noise baseline region (>6 or <0 ppm).

Because the magnetic field strength, breast coil, lesion size range, pulse sequence, and data acquisition measures used in this study were almost identical to those used by Huang et al (10) and Bartella et al (6), the same SNR threshold for choline peak was adopted to determine whether the proton (^1H) MR spectroscopic result was positive or negative. Results were deemed positive when the SNR was 2 or greater and considered negative in all other cases. To eliminate bias, histologic findings were revealed to the physicists (S.B.T. and W.H.) only after the SNR of the choline peak was determined.

MR Imaging and Image Review

Eligible patients who were scheduled to undergo diagnostic breast MR imaging were first imaged according to the standard departmental protocol (17). The biopsy-proved lesion was identified by reviewing the postcontrast T1-weighted MR images. Proton (^1H) MR spectroscopy of the lesion was then performed.

For eligible patients who were scheduled to undergo MR imaging-guided biopsy or needle localization, the lesion was first identified by performing pre- or postcontrast T1-weighted MR imaging (the former was preferred). Proton (^1H) MR spectroscopy of the le-

Results of Single-Voxel 1.5-T ^1H MR Spectroscopy in Previous Studies

Study*	No. of Malignant Lesions (n = 168)	No. of Benign Lesions (n = 112)	Sensitivity (%)	Specificity (%)	No. of True-Positive Findings (n = 149)	No. of True-Negative Findings (n = 97)	No. of False-Negative Findings (n = 19)	No. of False-Positive Findings (n = 15)	Positive Predictive Value (%)
Roebeck et al (13)	10	7	70	86	7	6	3	1	88
Kvistad et al (12)	11	11	82	82	9	9	2	2	82
Cecil et al (8)	23	15	83	87	19	13	4	2	90
Yeung et al (15)	24	6	92	83	22	5	2	1	97
Jagannathan et al (16)	32	14	81	86	26	12	6	2	93
Tse et al (14)	19	21	89	100	17	21	2	0	100
Huang et al (10)	18	12	100	87	18	8	0	4	82
Bartella et al (6)	31	26	100	88	31	23	0	3	91

Note.—Mean sensitivity, specificity, and positive predictive values for all studies were 87%, 87%, and 90%, respectively.

* Study reference numbers are in parentheses.

sion was then performed and followed by the scheduled MR imaging–guided biopsy or needle localization and surgical excision (17,18).

MR images were reviewed by one radiologist with 6 years of experience as a breast imaging specialist (L.B.). Sagittal fat-suppressed T2-weighted MR images, unenhanced sagittal fat-suppressed T1-weighted MR images, and sagittal fat-suppressed T1-weighted MR images obtained within the first 2 minutes after intravenous injection of contrast material were reviewed on a picture archiving and communication system workstation (GE Medical Systems) by the same radiologist. This radiologist could go back and forth through sequential sections and adjust the window and level settings at the workstation. Lesion size (largest measurement in one plane), morphologic features (mass vs nonmass), subcategories of nonmass-like enhancement, and final assessment categories were recorded according to the Breast Imaging Reporting and Data System (BI-RADS) lexicon for MR imaging (2).

Reference Standard

After MR imaging lesion data were recorded, histologic findings (reference standard) from histology reports were reviewed and compared with proton (^1H) MR spectroscopic results and MR image interpretations by the same radiologist (L.B.). Data were entered onto a computerized spreadsheet (Excel; Microsoft, Redmond, Wash).

Statistical Analyses

To evaluate the performance of proton (^1H) MR spectroscopy in the diagnosis of enhancing nonmass lesions, the sensitivity, specificity, positive predictive value, and negative predictive value of this technique in the assessment of 32 enhancing nonmass lesions were calculated after the MR spectroscopic and histologic results were compared. To assess the effect of proton (^1H) MR spectroscopy on the positive predictive value of biopsy, the positive predictive value of MR imaging in patients with BI-RADS category 4 or 5 lesions was calculated and compared with the positive predictive value of MR imaging after proton (^1H) MR spectroscopy was performed; histologic findings were used as the reference standard. Statistical analyses were conducted by using the statistical software program Stata, version 8.0, for Windows (Stata, College Station, Tex). The positive predictive values of MR imaging with and without proton (^1H) MR spectroscopy were compared by using methods described by Leisenring et al (19); the score test was used, and $P < .05$ was considered to indicate a significant difference.

Results

Patients

Between November 2003 and February 2006, 87 women with 88 lesions were successfully entered into the study (Fig 1). Of the 88 lesions, 32 (36%) were enhancing nonmass lesions, and these

constituted our study sample. These 32 enhancing nonmass lesions occurred in 32 women (mean age, 48.5 years [range, 20–63 years]). At the time of proton (^1H) MR spectroscopy, seven (22%) of 32 patients were undergoing diagnostic MR imaging to assess the extent of biopsy-proved cancer, and 25 (78%) were undergoing MR imaging–guided biopsy or needle localization for tissue diagnosis of a suspicious lesion detected at MR imaging. Indications for the initial diagnostic MR examination included screening of patients at high risk for breast cancer in 13 (41%) of the 32 patients, evaluation of disease extent in 16 (50%), and problem solving in three (9%).

MR Imaging Features and Histologic Findings

The median lesion size of these 32 enhancing nonmass lesions at MR imaging was 2.8 cm (range, 1.2–9.0 cm). Of the 32 lesions, 22 (69%) were BI-RADS category 4 lesions, three (9%) were BI-RADS category 5 lesions, and seven (22%) were BI-RADS category 6 lesions. Carcinoma was found in three (14%) of 22 BI-RADS category 4 lesions and in two (67%) of three BI-RADS category 5 lesions. All BI-RADS category 6 lesions were malignant. Thus, 12 of 32 enhancing nonmass lesions were malignant.

Regarding the enhancement pattern of the lesions, 19 (60%) of the 32 lesions showed focal clumped enhancement, 10 (31%) showed regional enhancement, one (3%) showed segmental enhancement, and two (6%) showed ductal enhancement (Fig 2).

At histologic analysis, 12 (37%) of the 32 lesions were malignant and 20 (63%) were benign. Cancer histologic type was DCIS in two (6%) lesions and invasive in 10 (31%) lesions (invasive ductal carcinoma in seven, invasive lobular carcinoma in two, and mixed invasive ductal and invasive lobular carcinoma in one). Sixteen (50%) of the 32 lesions consisted of benign histologic types, including fibrocystic changes, ductal hyperplasia, benign breast parenchyma, stromal fibrosis, fat necrosis, fibroadenoma, and sclerosing ad-

Figure 1

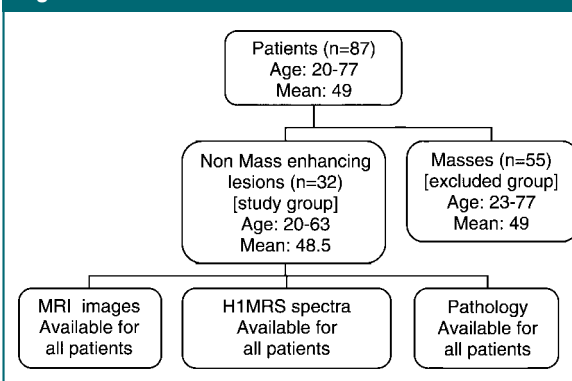


Figure 1: Flowchart of patients.

enosis. The remaining four (13%) lesions were high-risk lesions and included lobular carcinoma in situ, atypical lobular hyperplasia, atypical ductal hyperplasia, and chronic inflammation with atypia.

Proton (^1H) MR Spectroscopy

A positive choline peak was present in 15 (47%) of the 32 enhancing nonmass lesions. All 12 malignant lesions (100%) demonstrated a positive choline peak (Fig 3). The three (15%) of 20 benign lesions with false-positive results consisted of a fibroadenoma and fibroadenomatoid changes (Fig 4), a chronic inflammatory lesion with atypia, and a lesion with atypical ductal hyperplasia and columnar cell alteration. All 17 (53%) lesions with a negative choline peak were benign (Fig 5). The duration of imaging, initially 20 minutes, eventually decreased to 10 minutes by the end of patient accrual.

Diagnostic Performance

Because a choline peak was present in all 12 malignant lesions, proton (^1H) MR spectroscopy achieved 100% sensitivity (95% confidence interval [CI]: 74%, 100%) for the detection of breast cancer in this group of patients. A choline peak was absent in 17 (85%) of 20 benign lesions, yielding a specificity of 85% (95% CI: 62%, 97%) for proton (^1H) MR spectroscopy. When all 32 lesions in the study were included, the positive predictive value of proton (^1H) MR spectroscopy was 80% (95% CI: 52%, 96%) and the negative predictive value was 100% (95% CI: 80%, 100%).

To evaluate the effect that proton (^1H) MR spectroscopy would have had on the original MR imaging–based recommendation for biopsy, the seven BI-RADS category 6 lesions (biopsy-proved cancers at the time of initial MR imaging) were excluded from the calculations. Of the remaining 25 lesions, five (20%) were malignant and 20 (80%) were benign. According to the interpretation of diagnostic MR imaging results, all 25 enhancing nonmass lesions had suspicious characteristics and biopsy was recommended; the positive predictive value of MR imaging in this group

Figure 2



Figure 2: (a) Suspicious lesion detected at screening in 20-year-old woman with family history of breast cancer. Left breast shows focal clumped enhancement (arrow) in upper inner quadrant. Spectroscopy did not depict a choline resonance peak. MR-guided biopsy yielded fibroadenomatoid change and breast parenchyma. (b) Right breast in 43-year-old woman with family history of breast cancer (sister, age 41 years) who presented with right breast nipple discharge and pain demonstrates unilateral regional enhancement (arrow) at 12 o'clock position. Mammography showed dense breasts without suspicious findings. MR spectroscopy did not demonstrate a positive choline resonance peak. MR-guided biopsy yielded benign breast parenchyma. (c) Image in 57-year-old woman who presented with bloody nipple discharge from right breast demonstrates segmental clumped enhancement (arrow) of entire lower outer quadrant. No malignant findings were seen at mammography. Spectroscopy depicted positive choline resonance peak at frequency of 3.2 ppm, with SNR > 2. MR-guided biopsy and subsequent mastectomy yielded extensive ductal carcinoma in situ (DCIS) with high nuclear grade. (d) Left breast in 60-year-old woman with history of contralateral lumpectomy for DCIS shows ductal clumped enhancement (arrow) in retroareolar region. No choline resonance peak was detected at spectroscopy. Excision yielded fibrocystic change and ductal hyperplasia. Sagittal post-contrast fat-suppressed T1-weighted MR images (6.4/3.1).

was 20% (five of 25). Proton (^1H) MR spectroscopy demonstrated a choline peak in only eight lesions, five of which were malignant. The positive predictive

value in selecting women for biopsy significantly ($P < .01$) increased to 63% (five of eight), with no false-negative recommendations, when MR imaging

and proton (^1H) MR spectroscopy were combined. Biopsy could have been spared for 17 (68%) of 25 lesions, and no cancers would have been missed.

Figure 3

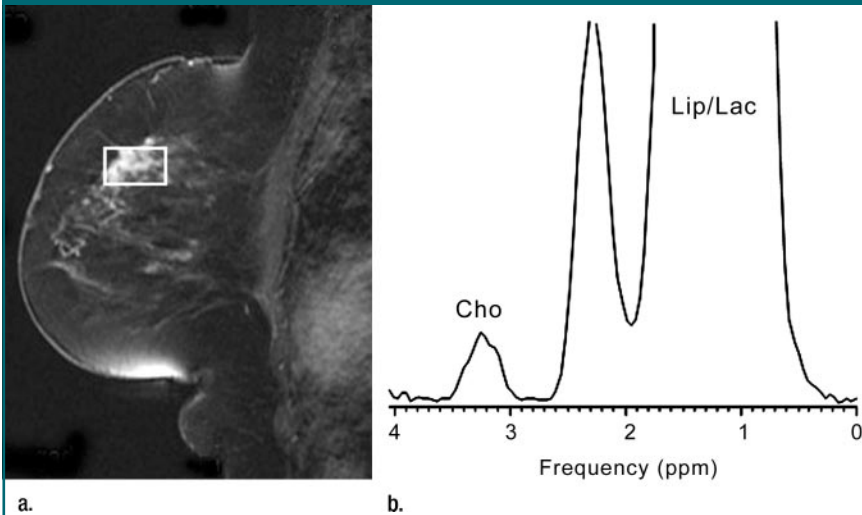


Figure 3: Palpable mammographically detected and biopsy-proved invasive lobular carcinoma in left breast of 56-year-old woman. **(a)** Sagittal fat-suppressed T1-weighted MR image (6.4/3.1) of left breast immediately after intravenous injection of gadopentetate dimeglumine shows 5-cm regional area of clumped enhancement in 12 o'clock axis, circumscribed by the voxel (white box). **(b)** Spectrum demonstrates choline (*Cho*) peak at frequency of 3.2 ppm, with SNR greater than 2. This is a true-positive finding. *Lac* = lactate, *Lip* = lipid.

Figure 4

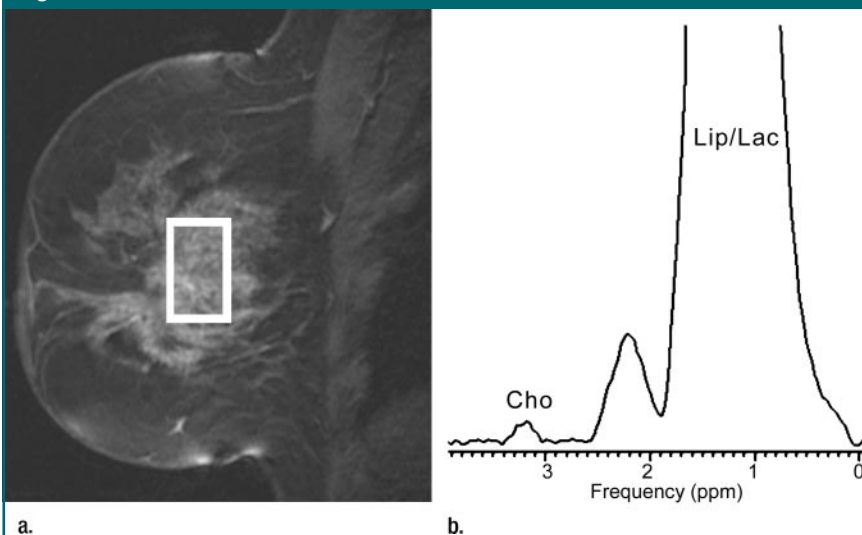


Figure 4: Suspicious nonmass lesion detected at extent-of-disease MR imaging in 43-year-old woman with biopsy-proved DCIS in central region of left breast. **(a)** Postcontrast sagittal fat-suppressed T1-weighted MR image (6.4/3.1) of left breast shows regional clumped enhancement in outer region, circumscribed by the voxel (white box). **(b)** Magnified spectrum demonstrates choline (*Cho*) resonance peak with SNR greater than 2. Excision yielded fibroadenoma and fibroadenomatoid changes. This is a false-positive finding. *Lac* = lactate, *Lip* = lipid.

Discussion

Proton (^1H) MR spectroscopy, usually performed with a single-voxel technique, may serve as a useful adjunct to breast MR imaging. In a study by Bartella et al (6), the sensitivity of proton (^1H) MR spectroscopy was 100% and the specificity was 88%; use of proton (^1H) MR spectroscopy as an adjunct to breast MR imaging would have significantly increased the positive predictive value of biopsy from 35% to 82%. If proton (^1H) MR spectroscopy had been used as an adjunct to MR imaging in 40 lesions with unknown histologic characteristics, biopsy might have been spared for 57% of the lesions and none of the cancers would have been missed. These data suggest that proton (^1H) MR spectroscopy may supplement breast MR imaging, reducing the number of benign biopsy results without compromising the diagnosis of breast cancer. To our knowledge, however, investigators in no prior studies have specifically investigated the use of proton (^1H) MR spectroscopy in enhancing nonmass lesions.

Most enhancing nonmass lesions, except those with homogeneous internal enhancement, have areas of normal glandular tissue interspersed between areas of abnormal enhancement (2). This interspersing of abnormal enhancement with normal glandular tissue in enhancing nonmass lesions theoretically could pose technical problems for proton (^1H) MR spectroscopy. Mobile lipids, present in areas of normal glandular tissue within the prescribed MR spectroscopy voxel, may produce spurious echoes (sidebands) that interfere with other breast metabolite signals and cause problems in identifying the choline resonance. Skill is necessary in planning MR spectroscopy to select an appropriate voxel size and a position that includes as much of the lesion as possible (to maximize the choline signal) while minimizing the presence of adipose tissue (which may create side-

band artifacts). Nonmass (as compared with mass) enhancing lesions assessed at MR spectroscopy generally include more adipose tissue because of the interspersing of normal and abnormal tissue in nonmass lesions.

Despite these potential pitfalls, we found that MR spectroscopy was useful in the evaluation of enhancing nonmass lesions. During lesion selection, lesions that were 1 cm in volume or larger were included; this size allowed enhancement to be seen filling most of the selected region. Although lipid sidebands were detected in our population, they did not obscure the choline resonance peak and therefore did not interfere with the detection of this peak. In our overall experience, these sidebands have been present in both types of lesions with no perceivable difference, although a separate study to analyze these spectra in further detail would be of interest.

Measurement of choline SNR can usually provide a quick answer, which is important if proton (^1H) MR spectroscopy is to be included in a clinical protocol for the diagnosis of breast cancer. Experience so far has demonstrated it to be a fairly accurate technique (6,10) in detecting breast cancer. Although absolute quantitation of choline concentration may be more desirable (7), this method may not be practical in the clinical setting; it requires additional time to collect data from an internal or external reference, and more errors may be introduced in calculations, such as corrections for longitudinal and transverse relaxation factors. The SNR can be affected by many factors in hardware and software setup, including data acquisition measures, pulse sequence, voxel size, coil sensitivity profile, and field strength. In our study, because the hardware and software setup and voxel size range were similar to those used in the preliminary study (6) and to those used by Huang et al (10), a choline SNR threshold of 2 was used to discriminate between benign and malignant lesions.

All cancers in the study were identified with proton (^1H) MR spectroscopy; there were no false-negative results. In prior studies of single-voxel proton (^1H) MR spectroscopy (8,13), researchers

Figure 5

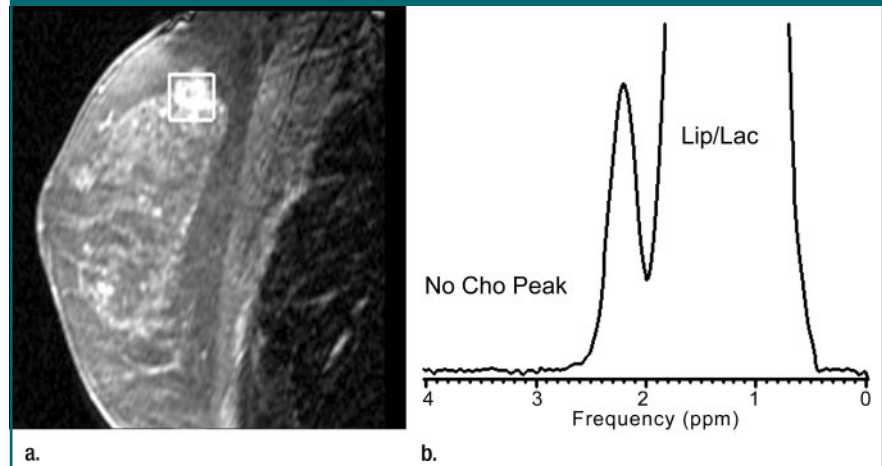


Figure 5: Suspicious nonmass lesion detected at screening MR imaging in 38-year-old woman with *BRCA-1* gene who was imaged at day 11 of her menstrual cycle. (a) Postcontrast sagittal fat-suppressed T1-weighted MR image (6.4/3.1) of left breast shows focal clumped enhancement in upper inner region, circumscribed by the voxel (white box). (b) Magnified spectrum demonstrates large lipid (*Lip*) peak, but no choline (*Cho*) resonance peak was observed at frequency of 3.2 ppm. This is a true-negative finding. *Lac* = lactate.

reported false-negative results that were attributed either to adjacent hemorrhage that resulted in inhomogeneities of the magnetic field or to patient motion due to the length of the examination time. Our exclusion of women with breast hematoma or clips associated with the lesions accounts, at least partially, for our better results. Also, the time required for MR spectroscopy, initially about 20 minutes, had decreased to approximately 10 minutes by the end of patient accrual. A choline peak was identified at proton (^1H) MR spectroscopy in cancers with a variety of histologic types, including 10 invasive cancers of varying histologic types (ductal, lobular, and mixed) and two DCIS lesions. The presence of a choline peak in both DCIS lesions is of interest, as previous study results have suggested that DCIS may not always demonstrate a choline peak (13,20). Three false-positive lesions, previously reported (6), were described in our study: a fibroadenoma, a chronic inflammatory lesion with atypia, and atypical ductal hyperplasia with columnar cell alteration.

It has been reported that enhancing nonmass lesions are less likely to have an ultrasonographic (US) correlate than are mass enhancing lesions (21). Even without a US correlate, malignancy may

be detected at MR imaging-guided biopsy (3,21). It may be particularly difficult to avoid a recommendation for MR imaging-guided biopsy with nonmass-like enhancement because of cyclical hormonal changes in the breast, especially in the absence of prior examination results for comparison.

Our study had limitations. The population of enhancing nonmass lesions, although larger than those previously reported in the literature, was small. There were only two cases of DCIS, limiting conclusions that could be drawn about MR spectroscopy in the assessment of in situ carcinomas; further analysis in larger series with more DCIS cases is necessary. Proton (^1H) MR spectroscopy of enhancing nonmass lesions in the breast was evaluated at 1.5 T without technical failures owing to lesion size. Because smaller lesions require a longer imaging time for data averaging to obtain sufficient SNR of the choline peak with a 1.5-T magnet, our study sample included only those MR imaging lesions that measured 1 cm or larger. The use of a single-voxel technique enabled only one lesion to be evaluated at a time. Technologic advancement and use of techniques that enable one to assess multiple voxels by preferably imaging the whole breast would im-

prove the clinical application of breast proton (^1H) MR spectroscopy.

In conclusion, in our experience, the proton (^1H) MR spectroscopic examination was quick and well tolerated in the clinical setting. Our study data show that the information obtained at proton (^1H) MR spectroscopy may decrease the number of biopsy recommendations for benign enhancing nonmass lesions. In our study, use of proton (^1H) MR spectroscopy as a supplement to breast MR imaging would have significantly increased the positive predictive value of biopsy for MR imaging–detected nonmass lesions from 20% to 63% and would have spared biopsy for 68% of lesions. In this study population, proton (^1H) MR spectroscopy had 100% sensitivity and 85% specificity for the detection of malignancy in enhancing nonmass lesions. Larger studies, ideally from multiple centers and with a variety of malignant and benign histologic findings, are needed to further evaluate the clinical application of breast proton (^1H) MR spectroscopy.

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