

Enhanced MR breast imaging

G.M. Newstead Department of Radiology, The University of Chicago, Chicago IL, USA.

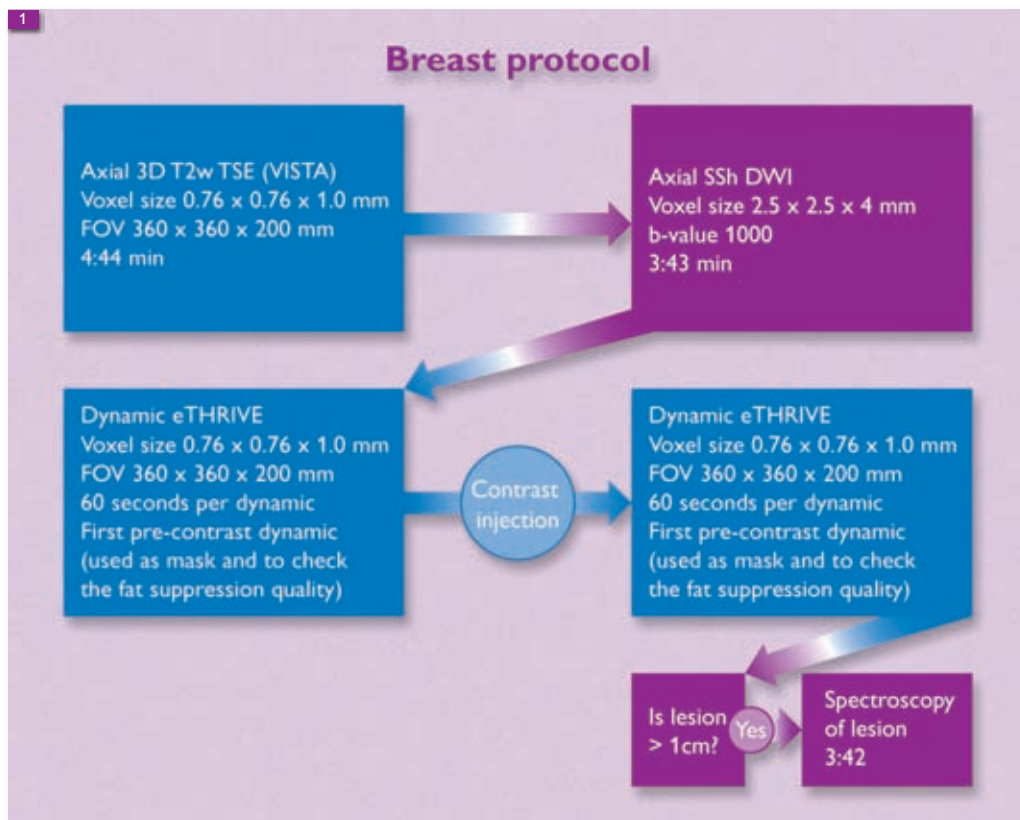


Figure 1. Diagnostic breast protocol with diffusion weighted imaging and spectroscopy.

The University of Chicago Medical Center (UCMC) is an integral part of the University of Chicago Hospitals. A team of specialized breast radiologists at the Center provides a full range of diagnostic services, including digital mammography, breast ultrasound and dynamic breast MRI, to more than 20,000 patients every year. Recently, the UCMC became the first site in the United States to use Philips Elite Breast Clinical Solution. Comprising the dockable MammoTrak patient support, integrated 16-channel SENSE MammoTrak Breast coil and software for accurate, efficient MR data analysis (DynaCAD), the Breast Clinical Solution provides very high image resolution, excellent breast coverage and an efficient workflow. This article describes the Center's pioneering work on the application of advanced MR technology to breast cancer.

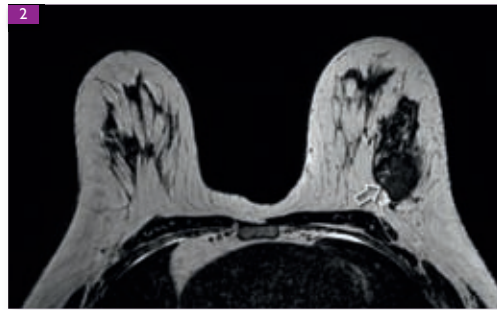
The UCMC has been using MRI for the detection and diagnosis of breast cancer for over 15 years. More recently, the Center has become especially committed to the use of dynamic contrast enhanced MRI (DCE-MRI).

MRI, together with other new diagnostic methods, has been shown to have the potential to dramatically improve the detection of cancer at a relatively early stage, when it is relatively easy to cure. New ACS guidelines recognize the importance of MRI for early detection of breast cancer. These new guidelines are likely to result in a dramatic increase in the number of women who receive MRI screening exams each year. Based on current guidelines, it is estimated that about 1.5 million women in the USA would qualify for this screening.

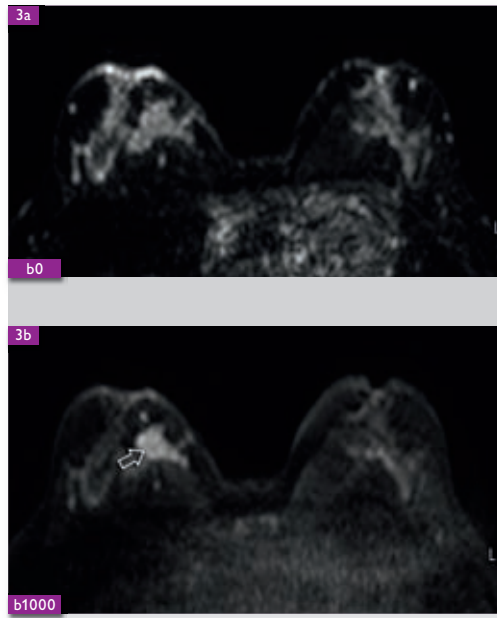
As the amount of screening increases, the need for increased specificity will also increase. In addition, while the sensitivity of MRI to invasive breast cancer is very high, improvements in sensitivity to early pre-invasive cancer, and even pre-cancerous lesions, are also needed. This will require improved application of conventional MR methods, improved image analysis and interpretation, and implementation of new methods including metabolic spectroscopy and diffusion-weighted imaging. In addition, a new approach to breast MRI, referred to as "high

► **New ACS guidelines show the importance of MRI for early detection of breast cancer.**

▶ Figure 2. 3D T2-weighted TSE (VISTA) axial bilateral image showing a malignant breast lesion (arrow).



▶ Figure 3. DWI of a malignant breast lesion (arrow).



▶ **At the UCMC, intensive use of MRI results in the discovery of 250 new cancers each year.**

spectral and spatial resolution” (HiSS) MRI provides improved fat suppression, contrast, and edge delineation.

At the UCMC, approximately 750 women receive screening and/or diagnostic MRI scans each year. Many of these patients receive MRI scans secondary to suspicious findings on mammography, primarily in order to search for additional lesions elsewhere in the breast.

Another large group of women comes from Dr. Olufunmilayo Olopade’s Cancer Risk Clinic. This is a specialized clinic within the UCMC. Dr. Olopade is a highly skilled hematology oncologist with proven expertise in cancer risk assessment. She conducts comprehensive evaluations of family history, genetic testing and other risk factors. The protocol followed at the UCMC calls for screening these patients for breast cancer with MRI and Ultrasound every six months, and X-ray mammography every year.

The intensive use of MRI results in the discovery of approximately 250 new cancers each year. The number of percutaneous biopsies (5%) is kept low through the use state-of-the art methods for MR imaging and image interpretation.

Diagnostic MRI

The standard clinical breast examination at the UCMC includes a number of scans, following the flow chart shown in Figure 1.

3D T2-weighted turbo spin echo

A 3D T2-weighted turbo spin echo (VISTA) scan is used to provide preliminary anatomic information and assist the prescription of subsequent scans. It is possible to use the signal intensity and morphologic evaluation of T2 weighted imaging detected masses to improve diagnostic specificity by matching the T2W sequence with the dynamic acquisition slice-by-slice for precise comparison. These scans are acquired rapidly by using multiple spin echoes combined with SENSE. In spite of the rapid acquisition, the image quality is excellent, and suspicious lesions are often detected on these scans. Lesion conspicuity on T2-weighted scans is useful for differentiating cysts and other benign lesions from cancers. Figure 2 is an example of a 3D T2-weighted TSE (VISTA) image, showing a malignant breast lesion.

Diffusion weighted imaging (DWI)

Bilateral diffusion weighted (DWI) scans are performed before contrast injection. Diffusion weighting is useful for detecting the increased cellularity of viable tumors, because the apparent diffusion constant is decreased by restricted diffusion of water inside cells. DWI may also be sensitive to ductal hyperplasia and ductal carcinoma in situ (DCIS) because water within the ducts, which normally diffuses freely, is confined inside intra-ductal cells.

Quantitative measurement of the “apparent diffusion constant” would require several different measurements with different applied gradient strengths. However, to conserve time, our clinical protocol simply uses a single diffusion weighted scan, and the resulting images are evaluated qualitatively to identify regions with an abnormal diffusion rate. An example of a diffusion-weighted image of a malignant breast lesion is shown in Figure 3.

Pre- and post-contrast scans

Bilateral scans are performed pre- and post-contrast. At the UCMC, “eTHRIVE” is used with “SPAIR” to provide fat-suppression with a spatial resolution of 0.76 x 0.76 x 1 mm times 200 slices per dynamic acquisition (Figure 4). This provides excellent morphologic detail pre- and post contrast injection, and images are acquired with temporal resolution of 60 seconds. A high acceleration factor of 6 is achieved using the new 16-channel SENSE MammoTrak Breast coil.

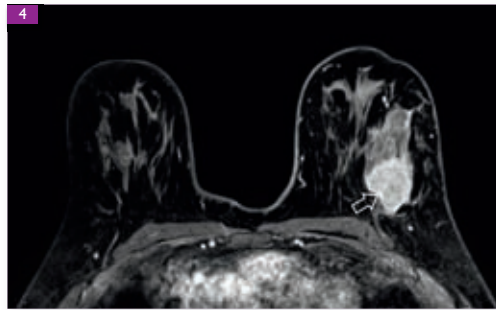
Reliable detection of DCIS requires rapid acquisition of the first post-contrast image because DCIS often enhances more rapidly than the surrounding normal parenchyma. Therefore, DCIS can be most clearly visualized by subtracting the first post-contrast images, acquired within the first 30 seconds (i.e. 60 seconds after injection), from the pre-contrast images.

High temporal resolution is also important because it allows accurate assessment of tumor blood flow. At short times after injection, uptake of contrast agent is determined primarily by blood flow and capillary permeability, while at longer times after injection, enhancement is strongly affected by the contrast agent distribution volume.

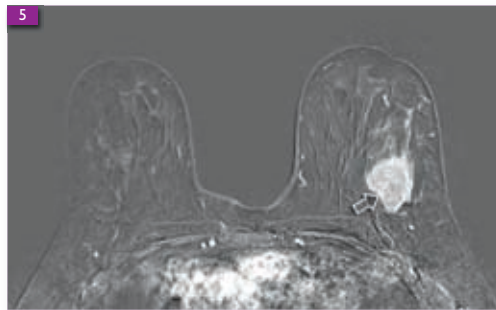
SENSE with acceleration factors of three or more is critical for proper evaluation of tumor blood flow and for detecting DCIS. With the 16-channel breast coil currently used at the UCMC, SENSE acceleration factors of three to six can be achieved without image distortion and with excellent signal-to-noise ratio.

DCE-MRI data are assessed in two ways. First, subtraction images are viewed, often in three dimensions, to assess the morphology and kinetics of enhancing lesions. An example of a subtraction image is given in Figure 5. Second, plots of signal intensity vs. time are evaluated for regions of interest that are manually selected to include suspicious lesions. These plots are classified using the method described by Kuhl et al, [1] to identify lesions that are likely to be malignant. More quantitative methods that correct for variations in the arterial input function, and for the “native” (pre-contrast) T1, are being developed for routine clinical use, and will soon provide reliable parametric images of tumor blood flow and contrast agent distribution volume.

For lesions that are at least a centimeter in diameter, metabolic single voxel spectroscopy is acquired using a PRESS sequence combined with outer volume suppression. This provides a non-invasive measurement of tumor metabolism and detects metabolites that are markers for



◀ Figure 4. eTHRIVE image (0.76 x 0.76 x 1 mm) dynamic series, showing a malignant breast lesion (arrow).



◀ Figure 5. Subtraction of eTHRIVE image (0.76 x 0.76 x 1 mm) dynamic series, with malignant breast lesion (arrow).

malignancy. The most commonly used marker is a high level of choline – a metabolite used in membrane metabolism that is elevated in malignant cells. Proton spectra can be acquired in five minutes with the new 16-channel MammoTrak breast coil, which also provides an improved signal-to-noise ratio.

Patient volume

The American Cancer Society (ACS) recently recommended the use of MRI in addition to mammography for annual breast screening for women with a 20%-25% or greater lifetime risk of breast cancer [2]. In addition, the Society recommends MRI in addition to mammography for women who:

- have a BRCA 1 or 2 gene mutation
- have a first-degree relative with a BRCA 1 or 2 gene mutation and have not been previously tested
- have received chest radiation treatment between the ages of 10 and 30
- are carriers or relatives of people with certain genetic mutations.

As a result, patient volume for screening with MR can be expected to increase in the years to come ■

► **The ACS recommends MRI with mammography for annual screening of women at risk.**

References

[1] Kuhl CK, Mielcareck P, Klaschik S, et al. *Dynamic Breast MR Imaging: Are Signal Time Course Data Useful for Differential Diagnosis of Enhancing Lesions?* Radiology. 1999; 211: 101-110.

[2] Saslow D, Boetes C, Burke W, Harms S, Leach MO, et al. *American Cancer Society Guidelines for Breast Screening with MRI as an Adjunct to Mammography.* CA Cancer J Clin. 2007; 57(2): 75-89.