Developments in Breast Imaging

Update on New and Evolving MR Imaging and Molecular Imaging Techniques

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KEYWORDS

• MR imaging • 3-T • Diffusion-weighted imaging • Abbreviated MR imaging
• Molecular breast imaging • Breast-specific γ-imaging • Positron emission mammography
• 18F-FDG PET

KEY POINTS

- The 3-T field strength MR imaging offers an increase in both temporal and spatial resolution over lower magnet strengths.
- Diffusion-weighted imaging is a short sequence that does not require contrast; it increases breast specificity and improves characterization of breast lesions as benign or malignant.
- Growing evidence shows that a shortened MR imaging examination could offer a high sensitivity for cancer detection with broader applicability than current MR imaging screening protocols.
- Molecular imaging techniques offer high sensitivity for cancer detection across breast densities, although relatively high radiation doses with these technologies must be taken into account.
- PET/MR imaging offers the potential of combining functional and anatomic imaging, directed to the breast and the rest of the body in the context of breast cancer staging.

INTRODUCTION

There have been exciting and varied developments in the field of breast imaging in recent years, developments encompassing multiple modalities with the promise of improving cancer detection. In addition to improved technological capabilities (such as higher magnetic field strengths), there has been growing interest in broader applicability for the breast MR imaging screening examination. In addition, there has been focus on and consideration for the additive impact that functional—in addition to anatomic—analysis of breast pathology have on better identifying and characterizing breast lesions; these developments apply both to the field of MR imaging (multiparametric approaches, including diffusion-weighted imaging [DWI]) and to the field of nuclear medicine (breast-specific γ-imaging [BSGI], positron emission mammography [PEM], and PET with fludeoxyglucose F 18/MR imaging [PET/MR imaging]), all of which are reviewed in this article. This article reviews these evolving breast imaging techniques with attention to the strengths, weaknesses, and applications of these varied approaches to breast imaging. In doing so, we hope to give the reader familiarity with the state of current developments in the field and to increase awareness of what to expect in future years in the field of breast imaging.

MR IMAGING

MR imaging of the breast has become a mainstay of breast imaging, both in the diagnostic realm

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(extent of disease, implant evaluation, workup of unknown primary in the context of axillary lymphadenopathy) and in the screening realm (high-risk women and, in certain cases, intermediate-risk women).[1]

Magnetic Field Strength: 3 T Versus 1.5 T

MR imaging protocol at 3 T

To allow for adequate spatial and temporal resolution, breast MR imaging should be performed at 1.0 T or greater field strength. We perform our MR imaging examinations using a 3 T magnet (TIM Trio, Siemens Medical Solutions, Erlangen, Germany) with the patient in prone positioning using a dedicated surface breast coil (Sentinelle 16 channel coil, Invivo, Gainesville, FL). Our standard imaging protocol includes a localizing sequence followed by axial T2-weighted sequence (TR/TE, 7220/84), an axial T1-weighted non–fat-suppressed 3-dimensional fast spoiled gradient-recalled echo sequence (TR/TE, 4.01/1.52; flip angle, 12°; matrix, 384 × 384; field of view, 270 mm; section thickness, 1 mm) followed by the same axial T1-weighted fat-suppressed 3-dimensional fast spoiled gradient-recalled echo sequence performed before and 3 times immediately after a rapid bolus injection of 0.1 mmol/kg of gadopentetate dimeglumine (Gadovist, Bayer Healthcare, Whippany NJ) per kilogram of body weight at an injection rate of 2.0 mL/s via an intravenous catheter followed by a saline flush. The first contrast-enhanced dynamic image corresponds with approximately 100 seconds after injection. The total duration of the dynamic study is approximately 7 minutes. After the examination, subtraction images are obtained by subtraction of the precontrast images.

Advantages of 3 T imaging

Breast imaging at 3 T allows for an increase in both temporal and spatial resolution over lower magnet strengths. Signal-to-noise ratio (SNR) improves linearly with increasing field strength. This improvement in SNR offers the potential for a faster imaging time and increased spatial resolution, although real-time factors yield an SNR that is usually 1.6 to 1.8 times the SNR at 1.5 T, rather than the theoretically expected doubled SNR.[2] The 3 T strength also offers better fat suppression (although B0 homogeneity may be more difficult at 3 T) because there is increased spectral separation of fat and water resonance at higher field strengths. The more homogenous and more effective fat suppression should translate into increased lesion conspicuity.

It is possible that 3 T is especially effective in conjunction with parallel imaging, a technique that uses decreased sampling of k space lines enabling reduced phase encoding steps by an acceleration factor R; this in turn allows for decreased acquisition times by a factor of 1.5 to 3.0,[3] with excellent spatial resolution.[4,5]

There are multiple studies demonstrating excellent lesion detection at 3 T with high sensitivity,[6,7] but it is difficult to quantify definitively the clinical value of breast MR imaging at 3 T versus 1.5 T, in particular because differences in coils and scan parameters complicate meaningful comparisons.[8] One prospective study looked at 31 women with known malignant and benign lesions who had a 1.5 T breast MR imaging scan followed by a 3 T scan 24 to 48 hours later; the authors found improved lesion conspicuity of both benign and malignant lesions at 3 T versus 1.5 T; however, this difference did not achieve significance.[9]

Disadvantages of 3 T imaging

There are potential disadvantages at higher magnetic field strengths: both chemical shift and susceptibility artifacts may be more evident at 3 T compared with 1.5 T. In addition, the energy deposited into tissue at 3 T is approximately 4 times greater at 3 T compared with 1.5 T,[2] because radiofrequency energy increases exponentially with field strength. For this reason, there is a greater risk of tissue heating and burns at higher magnetic field strengths. To maintain the specific absorption rate, the US Food and Drug Administration mandated limits (4 W/kg averaged over the body for 15 minutes),[10] protocol changes such as decreasing slices per TR, decreasing flip angle, and longer a TR may need to be used. However, such changes come at the expense of decreased SNR, tissue contrast, and breast coverage. In addition, hardware and implants that are compatible with 1.5 T systems may not be safe at 3 T. If there is any concern for patient safety in the context of a 3 T magnet, the study should be performed on a 1.5 T magnet instead. Finally, it is worth noting that although a 3 T magnet costs more than a 1.5 T magnet, billing is the same for both field strengths.

Diffusion-Weighted Imaging

DWI operates through exploiting the molecular diffusion of water through tissue. The mobility of the water molecules is altered by factors such as tissue cellularity; the degree of tissue cellularity and membrane integrity impacts water diffusion with resultant signal changes. Thus, DWI has the ability to improve breast cancer detection when the cellular structure alters owing to cancer histologic make-up. Because DWI does not require a contrast agent and is a relatively rapid sequence, often taking only 2 to 3 minutes,[11] DWI is a