Contrast enhanced breast MR imaging is an important tool for the detection and characterization of breast carcinoma. Among the indications of breast MR imaging that is supported by the literature are cancer screening in high risk patients, evaluation of patients with newly diagnosed breast cancer (including screening of the contralateral breast), monitoring treatment response in patients undergoing primary chemotherapy, and evaluation of patients with metastatic cancer (axillary or other site) from unknown primary. Disadvantages of MRI include its high cost and relatively lower specificity leading to more follow-up examinations or biopsies.

Breast cancer is a complex disease. Microarray analysis has identified breast cancer subtypes with distinct genetic features. The tumor phenotype is a result of the genotype and its interaction with the microenvironment. Several recent reports showed that basal-like (triple negative) cancers were different from other cancers. These cancers were more likely smooth, rounded masses without spiculations or calcifications and more likely had rim-enhancement on MRI. Breast cancers arising in carriers of germline BRCA1 mutations are often of basal-like type and may exhibit benign morphological features: including oval shape and smooth margins, described as ‘pushing margins’. Studies of receptor status in correlation with MRI kinetics revealed that kinetic characteristics of ER positive and negative cancers showed some significant differences on MRI. ER negative tumors showed strongest initial enhancement, shortest time to peak enhancement and strongest washout. There was no significant difference shown to correlate with Her-2/neu status. Yet, there is a substantial overlap between the MRI imaging phenotype and underlying molecular biology of the tumor in the various subgroups. Adjunct MRI methods may add diagnostic information about the cancer reflecting the various underlying genetic subtypes. It was shown that important prognostic information can be deduced from MR spectroscopy, DCE MRI and DWI.
MR Spectroscopy (MRS)
MRS shows small differences in the magnetic field in different chemical compounds to measure their concentrations. MRS may discriminate between normal, malignant, necrotic, or hypoxic tissue states in vivo. Breast proton magnetic resonance spectroscopy (1H MRS) measures of the cell membrane marker choline (Cho) compounds have shown elevated levels in malignancies. The use of breast MR spectroscopy in conjunction with MR imaging significantly increases the positive predictive value of MR imaging and decreases the number of benign biopsy results. Investigators have reported sensitivities of 70%–100% and specificities of 67%–100% for 1H-MRS. Additionally, it has been suggested that Cho levels may not be as greatly elevated in some breast cancers as in others, this variation determined by the biologic aggressiveness or other features. In addition to being used for breast cancer diagnosis, in vivo 1H MR spectroscopy has also been used to monitor breast cancer response to chemotherapy, with spectral changes reflecting chemical and biological changes. It has also recently been reported that changes in breast tumor choline levels detectable at higher field strengths may be a predictive marker of treatment response very early after the first dose of chemotherapy.

The single-voxel 1H MRS technique has limitations. The variable and intense contribution of adipose breast tissue to the MR spectra makes B0 shimming more difficult due to problems with susceptibility. A non-homogeneous static field may affect the performance of chemically selective fat suppression and water suppression in localized MRS. A long echo time and fat suppression can be used to suppress the lipid sideband; and improved water- and lipid-suppression techniques are helpful. Scanning at 3.0 T improves the MRS conspicuity of metabolites in breast tissues compared with 1.5-T imaging.

Dynamic Contrast-Enhanced (DCE) MRI
With DCE MRI, a gadolinium-based contrast agent is injected following one or more image volumes and then further volumes are taken as fast as possible. Indirect measurement of tumor permeability and flow data can be obtained by measuring the rate of contrast enhancement, by $K_{\text{trans}}$ (forward transfer constant from vascular space to the tumor), $k_{\text{ep}}$ (reverse rate constant from tumor to the vascular space), and $v_e$ (extravascular volume fraction) calculations. It is difficult to acquire at the same time both high-spatial-resolution data to visualize morphology and high-temporal-resolution data for contrast kinetic analysis: the high-resolution images that are necessary for morphological interpretation require a relatively long acquisition time. Fewer slices or reduced matrix size will speed acquisition, but at the expense of decreased spatial resolution or coverage. Multiple quick acquisitions for enhancement dynamics highly correlated with final benign or malignant histopathology results and increased diagnostic accuracy when compared to few time points.

Diffusion-Weighted Imaging (DWI)
DWI sequences are recently being considered for clinical application for breast cancer diagnosis. DWI reflects biophysical characteristics such as cell density, membrane integrity, and microstructure. Two diffusion sequences with different b-factors can be used to measure the degree of molecular mobility quantitatively, by calculating the apparent diffusion coefficient (ADC) value. Recent DWI studies have shown high sensitivity for cancerous breast lesions by detecting lower ADC values in comparison to those of normal breast tissue or benign breast tumors. Low ADC possibly reflects the increased cell density of malignant tumors. An additional promising application is follow up of patients who receive primary chemotherapy: ADC value increase in cancers may be the earliest indicator of treatment response and efficacy. This ADC increase supposedly related to tumor cell death leading lower cellularity.
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