The Efficiency of Diffusion Weighted MRI and MR Spectroscopy On Breast MR Imaging

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ABSTRACT

The main purpose of breast magnetic resonance imaging (MRI) in radiologically routine is to establish an imaging protocol that will create high quality images with a short period of time. For this purpose, an imaging protocol should include a conventional breast MRI and contrast enhanced sequences. Proton MR spectroscopy (MRS) and diffusion weighted imaging (DWI) are important MR techniques for evaluation of complicated breast lesions. In this article, we will evaluate the technical properties of the MRS and DWI as additional MR imaging.

Key words: Breast, diffusion weighted MRI, MR spectroscopy

Introduction

Due to the rapid developments in magnetic resonance imaging (MRI) techniques, the contrast and spatial resolution of the resultant images have increased and MRI has definitely gained a significant role in breast imaging. According to the data provided by the EUSOMA group, the use of breast MRI is recommended especially in newly diagnosed invasive lobular carcinoma, and in lesions over 1cm where the results of conventional imaging methods are controversial and the treatment decisions may be affected, and for local staging (1). Moreover, its routine use as an advanced imaging method is increasing in high-risk patients in combination with conventional methods for screening purposes. In the long-term it is expected that with rapid technological developments, breast MRI will preserve its superiority as a complementary advanced diagnostic method.

Although they are not yet part of routine breast imaging methods, magnetic resonance spectroscopy (MRS) and diffusion-weighted imaging (DWI) are imaging methods which offer additional data to conventional methods especially in the preoperative period, and are used especially in cases with diagnostic difficulties. This article presents information on the techniques and clinical applications of MRS and DWI.

Diffusion Weighted Imaging (DWI)

Diffusion-weighted imaging (DWI) is an effective diagnostic method in identification of breast lesions (2). DWI is an MR sequence sensitive to changes in micro-diffusion movement of water molecules in intracellular and extracellular space (3). It basically provides functional information based on microscopic movement of water molecules within tissues. Its efficacy on evaluation of cell density in breast lesions has been proven by previous studies in the literature (4). Restricted diffusion within the tumor appears as high signal on DWI, and as low signal on apparent diffusion coefficient (ADC) maps, and it represents high cellular density (3, 4). ADC, which is calculated by a computer program using a mathematical formula based on DWI, allows quantification of diffusion within tissues. ADC based studies showed that DWI is not only effective in discrimination of benign-malignant breast lesions but also indicates tumor aggressiveness (5, 6). Recent studies revealed that it has a high sensitivity in the evaluation of the response of breast masses to neoadjuvant chemotherapy during the early period (7, 8).

Due to the technological developments in the main magnetic field and used gradients in magnetic resonance imaging (MRI) devices, especially the 1.5 and 3T magnets, DWI can be obtained by high spatial resolution and signal/noise ratio, and shorter examination time (4). The DWI is characterized by the "b" value (s/mm^2) that indicates the strength of the diffusion gradient. The diffusion weight of the resulting image increases as the "b" value increases, and in contrast to this in low "b" values, the T2-weight of the image becomes more apparent. In daily practice, "b" values equal to or less than 400 s/mm^2 tissue microcirculation effects DWI and results in an artifact called false negative diffusion due to microperfusion (9, 10). Previous studies recommended a "b" value of $750 - 1000 \text{ s/mm}^2$ (11). However,

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Figure 1. a-g. A giant fibroadenoma in a forty-nine-year-old woman; A high-density BI-RADS IV lesion with lobulated contours is observed at the junction of the upper outer-inner quadrant in the right CC mammography (a). The breast ultrasonographic examination revealed a hypoechoic lesion with macrolobulated contours (b). Conventional breast MRI examination, fat-suppressed T2-weighted image (c), post-contrast digital subtraction T1-weighted images (d) show a lobulated lesion in right breast outer quadrant with significantly higher intensity as compared to normal breast tissue (arrows). On dynamic MR imaging (e), a type 1 (benign pattern) kinetic curve is obtained by sampling of the lesion (L1). Although the lesion located at the right breast showed higher intensity than normal breast tissue on DWI (yellow arrows), (f), there was no diffusion difference when compared to normal breast tissue by ADC map (g)

in studies using a high “b” value, image distortion may occur due to magnetic susceptibility artifact (12, 13).

An EPI (“echo-planar-imaging”) T2 sequence is preferred in diffusion-weighted imaging due to its ability to allow very fast imaging in both research and clinical applications. The diffusion encoding gradients are applied as bipolar pairs. While the smallest lesion size that could be detected in the breast by DWI was initially 1 cm, recent studies reported that lesions 0.4cm in size were detected (10, 11).

A faster imaging time and not requiring contrast agent are the most important advantages of DWI. However, its main disadvantages are patient motion, magnetic susceptibility and chemical-shift artifacts. Many studies advocate that DWI should be included as part of routine breast MRI and it is suggested that unnecessary surgical procedures and biopsies will be reduced in this manner (12). Especially in patients with locally advanced breast cancer, it has been proposed as a highly effective imaging modality to reveal response to neoadjuvant chemotherapy in the early period (14, 15).

Diffusion tensor imaging (DTI) is a promising, new diffusion MRI technique that helps to reveal the microscopic properties of tissues (16). This method calculates fractional anisotropy and relative anisotropy in the tissue, and shows molecular diffusion in planes perpendicular to each other within the tissue. It has been reported that the obtained numerical values exhibit tissue’s diffusion information more effectively than DWI and ADC (16). It was initially used in examinations for the white matter of the central nervous system, and recent studies on its whole-body application have been published (17). Studies focusing on the breast indicate that it may contribute to the differential diagnosis of breast masses (18).

Englander and colleagues first used diffusion-weighted imaging of the breast in 1997 (19), while Sinha et al. (12) used this method for breast masses in 2002. Since then, the frequency of DWI has increased in breast imaging, and its applications have become widespread. Its superiority to conventional breast MR examinations, especially in re-

vealing response to medical therapy and differentiation of malignant and benign lesions in the pre-operative period have been demonstrated by studies (20, 21). Our experience on the subject is in accordance with the literature, in BIRADS-4 or BIRADS-5 lesions, DWI enables evaluation of both the primary lesion and when present, the contralateral lesion. Similarly, it contributes to conventional breast imaging methods in the differentiation of benign and malignant masses in the pre-operative period (Figure 1).

MR Spectroscopy

Magnetic Resonance Spectroscopy is an MR technique that provides information on the relative concentration of biochemical components within tissue, non-invasively. Pilot studies have shown that single-voxel” proton (hydrogen) MRS is a reliable method in in-vivo biochemical evaluation of breast lesions (22). Reliable biomarkers for breast cancer such as choline, phosphocholine, taurine and glycerophosphocholine can be quantitatively detected with MRS (23). By proton MRS, choline-containing metabolites create a peak around 3.2 ppm (3.14 to 3.34 ppm), and the peak that contains total choline is called (“tCho”). Detection of choline-containing metabolites in breast lesions indicates increased cellular metabolism, thereby indicating the presence of malignancy (23). In various studies on MRS, a relationship between presence of choline-containing metabolites and HER2 / neu expression or aggressive tumor phenotype has been shown (24, 25). In addition, the roles of MRS in evaluation of axillary lymph node metastasis and response to neoadjuvant chemotherapy have also been investigated (26).

Magnetic resonance spectroscopy can be obtained by using MRI devices with high main magnetic field strengths. The main magnetic field strength that will be used for this purpose should be 1.5 T, minimum. In previous studies of MRS on breast masses, usually a single voxel spectroscopic imaging was preferred (26). MRS is generally used as an additional method to conventional and dynamic breast MR imaging modalities. After a lesion is detected by conventional methods, and its borders are determined by dynamic breast MRI examination, a single voxel is placed into the center of the lesion and an MRS is obtained. The voxel size ranges from 4.8 to 8 mL in different studies. After the

Figure 2. a, b. A forty-three-year-old woman with invasive lobular carcinoma on the left breast; Conventional breast MRI examination, post-contrast digital subtraction sagittal T1-weighted images (a) multifocal, lobulated masses are present in the outer quadrant of the left breast that show significantly higher intensity as compared to normal breast tissue (arrows). A choline peak is observed at 3.2ppm (arrow) on the single voxel MR spectroscopy view of the same patient (b)

magnetic field homogeneity has been achieved within the voxel, imaging is performed by the PRESS (“point-resolved spin-echo sequence”) sequence. The CHES (“chemical shift selective excitation”) sequence that applies frequency selective suppression is used in order to suppress water and oil. Time required for an average measurement by single voxel MRS technique is approximately 15 minutes.

Regardless of the method used, MRS contributes to the differentiation of breast masses with high specificity (88%), and low and variable sensitivity (73%) rates. No differences were detected between methods used in 3 T and 1.5 T devices in terms of diagnostic advantage in breast lesions (27). Our experience with single voxel MRS examinations showed that the presence of choline peak provides diagnostic contribution in addition to other breast MRI images, but similar to the literature, its sensitivity and specificity was low (Figure 2).

Magnetic resonance spectroscopy and DWI imaging are considered as experimental imaging methods in the latest guidelines published in the literature (28). With standardized, prospective, multicenter studies that will be held in the near future, it is expected that advanced imaging methods used in the differential diagnosis of breast lesions will be included in guidelines within the scope of routine screening planning (27).

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