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Contrast-enhanced and unenhanced diffusion-weighted imaging of the breast at 3 T

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AIM: To evaluate the effect of intravenous gadolinium contrast agent on diffusion-weighted sequences and apparent diffusion coefficient (ADC) measurements at 3 T.

MATERIALS AND METHODS: Sixty-two biopsy-proven breast lesions were included in this prospective study. Magnetic resonance imaging (MRI) was performed at 3 T, using four echo-planar diffusion-weighted sequences (7,100 ms repetition time, 84 ms echo time) with b-values of 0 and 850, and 0 and 1,000 s/mm^2. The first pair of DWI sequences was taken before intravenous contrast medium injection. The second pair of sequences was taken 6.5 minutes after intravenous contrast medium administration (right after the dynamic T1 sequence). A freeform region of interest (ROI) was drawn inside the lesion excluding adjacent normal tissue, necrotic, or cystic components and ADC values were calculated. The paired samples *t*-test was used to assess differences between ADC measurements before and after intravenous contrast medium administration. Sensitivity, specificity, positive predictive value, negative predictive value, and area under the curve were calculated for each diffusion sequence.

RESULTS: Twenty-seven malignant and 35 benign lesions were analysed. Fifty-eight lesions were masses, and four lesions were non-mass-like enhancements (NMLEs). Two of the NMLEs were malignant, and two were benign lesions. The contrast-enhanced ADC measurements were lower than the unenhanced measurements on b=850 and 1,000 s/mm^2 ($p<0.05$). The receiver operating characteristic (ROC) analysis displayed similar area under the curve values between the different diffusion sequences.

CONCLUSION: The injection of intravenous contrast medium reduces ADC values; however, the effect of contrast medium is modest. Sensitivity and specificity are not significantly affected.

Introduction

Magnetic resonance mammography (MRM) is an established method for the evaluation of breast lesions. It is increasingly used for accurate diagnosis of inconclusive breast lesions shown in mammography or ultrasonography, in the preoperative evaluation of known breast cancer, and for screening women at risk of breast cancer. The main

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advantage of MRM is the very high sensitivity (89–100%)[1–4] and negative predictive value (NPV; 0.97–1).[5] Conversely, standard contrast-enhanced MRM provides moderate specificity in breast lesion characterisation (77–83%)[6,7].

Additional magnetic resonance imaging (MRI) sequences added to the basic MRM protocol, such as diffusion-weighted imaging (DWI), have been considered to improve the specificity of MRM. Several studies have concluded that DWI can significantly improve the differentiation between malignant and benign breast lesions.[8–11] Consequently, DWI is widely used in breast MRI protocols, mainly as part of multiparametric contrast-enhanced (CE) MRI.

Traditionally, the DWI sequences are performed before intravenous (IV) contrast medium administration; however, there are advantages when DWI series are taken after IV contrast medium administration. On the one hand, it enables the reorganisation of the MRM sequences, as the dynamic T1 sequence with IV contrast medium could be acquired as early as possible, reducing the risk of motion artefacts that tend to occur later during the examination due to patient fatigue. On the other hand, it has been proposed that in DWI taken after IV contrast medium administration, the microperfusion-induced apparent diffusion coefficient (ADC) elevation is suppressed, increasing the conspicuity of lesions demonstrating hypercellularity (essentially the malignant lesions).[12]

The purpose of the present study was to evaluate the change of ADC measurements before and after intravenous contrast medium injection in the characterisation of breast lesions.

Materials and methods

In this study, approved by the local ethics committee, 70 patients who underwent MRM were evaluated. Eight examinations were excluded from the study because of motion artefacts and misregistration between the different diffusion sequences. A total of 62 examinations were included in this study. The indications for MRI examination were the preoperative evaluation of the extent of a newly diagnosed breast cancer, equivocal findings in mammography or ultrasonography and screening of a high-risk population.

The MRI examinations were performed on a 3 T MRI system (Signa HDx, GE Healthcare, Milwaukee, WI, USA), with a dedicated bilateral phased-array breast coil (four-element two-channel coil, one channel per breast) and the woman in the prone position. All patients were carefully instructed to breathe normally and not to move during the entire examination. MRI examinations for all premenopausal women were performed during the second week of the menstrual cycle, and for postmenopausal women under hormone-replacement therapy, 6 weeks after treatment discontinuation. All malignant lesions were confirmed histologically.

Breast MRI protocol included axial T2-weighted fast spin echo (T2-FSE) sequence (3,600 ms repetition time [TR], 100 ms echo time [TE], 416×256 matrix, 4 mm section thickness, 0 mm spacing), axial short TI inversion recovery sequence (STIR; 3860 ms TR, 90 ms TE, 512×256 matrix, 4 mm section thickness, 0 mm spacing), and a three-dimensional fat-suppressed T1-weighted (3D-T1-FS) VIBRANT dynamic sequence (10° flip angle, 4,900 ms TR, 2 ms TE, 1.2 mm section thickness, 350×350 matrix) in the axial plane once prior to and five times after intravenous injection of 0.1 mmol/kg body weight of gadopenate dimeglumine (Magnevist, Bayer Schering Pharma, Berlin, Germany) or gadodiamide (Omniscan, GE Healthcare) with a power injector, followed by a 20 ml saline solution flush, over a period of 5–8 seconds. Each sequence lasted 1.3 minutes. Over the whole dynamic series, the system's receiver adjustment remained unchanged. Axial DWI sequences were acquired before and after intravenous contrast medium administration. Contrast-enhanced DWI sequences were performed right after the VIBRANT sequence (6.5 minutes after contrast medium administration). The DWI sequences were generated using a two-dimensional (2D) spin-echo (single-shot) echo-planar imaging (EPI; 6,000 ms TR, 90 ms TE, 4 mm section thickness, 96×128 matrix, 4 mm spacing). Sensitising diffusion gradients were applied in three orthogonal directions (x, y, z) with b-values of 0, 850, and 1,000 s/mm^2. The DWI images were post-processed with commercial software in a dedicated DICOM workstation (Advantage Windows, version 4.2; using FuncTool, GE Healthcare). The ADC maps were calculated automatically by the software with the use of the equation described by Stejskal and Tanner13 from the trace-weighted images with b values of 0–850 s/mm^2 and 0–1,000 s/mm^2. The formula is denoted as:

$$ADC = \ln(S_1/S_2)/(b_2-b_1),$$

where $b2 > b1$, S is the signal intensity and b is the b-value.

The MRM studies were reviewed by two radiologists in consensus, one radiologist having >15 years of experience in breast MRI and the other with 8 years of experience in general radiology, including the reading of breast MRI studies.

Taking into account the lesion morphology and enhancement at the second post-contrast T1 sequence, the region of interest (ROI) was drawn manually at the DWI within the lesion borders, excluding cystic or necrotic components. The ROIs were drawn on unenhanced sequences and automatically copied on contrast-enhanced sequences. Then the ROI placement was further adjusted manually to account for image changes, due to Eddy current effects or minor patient motion between the different diffusion series. When more than one ROI was drawn at the same lesion, the one with the lowest ADC value was accepted.

The paired samples t-test was used to determine whether there was a statistically significant difference between the pre- and post-contrast ADC measurements. Sensitivity, specificity, NPV, positive predictive value (PPV), and area under the curve (AUC) were calculated for each diffusion sequence, using ROC curve analysis. The significance level was set at 0.05. Statistical analysis was performed using SPSS for Windows (SPSS version 23, Chicago, IL, USA).

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