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Original Article

The added value of qualitative and quantitative diffusion-weighted magnetic resonance imaging (DW-MRI) in differentiating benign from malignant breast lesions

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ABSTRACT

Objective: To evaluate the role of diffusion-weighted magnetic resonance imaging (DW-MRI) with calculation of the apparent diffusion coefficient (ADC) value in characterizing benign and malignant breast lesions.
Patients and methods: The imaging data of thirty-nine female patients (mean age 48 years) who underwent breast MRI using conventional pulse sequences. DW-MRI and dynamic contrast enhanced (DCE) study were all analyzed and correlated with the results of histopathological evaluation.
Results: Forty-six breast lesions were detected in the thirty-nine patients of the study. According to the histopathological analysis, there were 27 malignant lesions (58.69%) and 19 benign lesions (41.31%). The malignant lesions showed a mean ADC value of $0.93 \pm 0.42 \times 10^{-3}$ mm^2/s. and the benign lesions showed a mean ADC value of $1.54 \pm 0.43 \times 10^{-3}$ mm^2/s. The receiver operating characteristic (ROC) curve could identify an ADC 1.26×10^{-3} mm^2/s as a cut-off value to differentiate between benign and malignant lesions with sensitivity and specificity of 89% and 94.7% respectively.
Conclusion: DW-MRI is useful for differentiating malignant and benign breast lesions, increasing the specificity of breast MRI. DW-MRI doesn't cause significant increase in the total examination time and is recommended to be incorporated in the standard breast MRI protocol.

1. Introduction

The investigation and preoperative staging of breast cancer are done based upon mammography, ultrasonography, and dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI). Diffusion-weighted imaging (DWI) now plays an important role in differentiating lesions detected by breast MRI [1–3]. DCE-MRI has a tremendous sensitivity in discovering breast tumors, but has a comparably lower specificity. This is attributed to the multiple coinciding characters among benign and malignant lesions [4].

While identification of different imaging criteria of lesions such as shape, margins and internal architecture besides the enhancement pattern gives great help in differentiating benign from malignant lesions, DWI gives relevant qualitative and quantitative data regarding structural tissue changes at a cellular level, and thus can be used in the differentiation between benign and malignant lesions, especially those lesions hidden on conventional MRI pulse sequences [5–8].

The relevant data obtained with DW-MRI is advantageous as DWI does not require the administration of intravenous contrast agents, so it can be used in patients with impaired renal function. Using the echo-planar technique, DWI can be done in satisfactorily short time that doesn't cause significant increase in MRI examination time [9].

DW-MRI gives qualitative and quantitative data about the diffusion of water molecules in a given tissue (either high or low diffusion). Tissues with restricted diffusion appear hyperintense (bright) while tissues with less restricted (facilitated) diffusion appear hypointense. From the registered DW images, apparent diffusion coefficient (ADC) maps can be generated, which represent the quantitative evaluation of DW images. The objective measurement of the ADC value of a certain area can be done through applying regions of interest (ROI) on the ADC map calculated from the diffusion weighted images obtained at multiple *b* values [10,11].

Areas of restricted diffusion usually represent highly cellular lesions and exhibit low ADC values in comparison to the less cellular lesions

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Table 1
Distribution of the detected contrast enhanced lesions according to the morphological criteria and type of dynamic curve in correlation with histopathological results.

Type of dynamic curve	Malignant group "n = 27"	Benign group "n = 19"
I	0/27 (0.0%)	11/19 (57.8%)
II + Malignant Criteria	6/27 (22.2%)	4/19 (21.1%)
II + Benign Criteria	3/27 (11.1%)	4/19 (21.1%)
III	18/27 (66.6)	0/19 (0.0%)

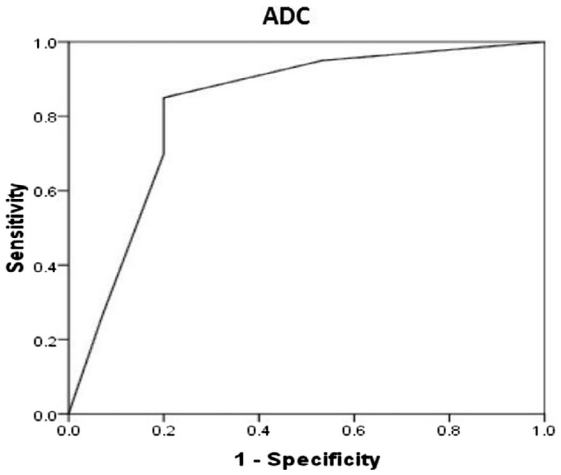

Fig. 1. ROC curve analysis for the ADC value.

that reflect lower intensity in DW images and exhibit higher ADC values [12].

The aim of the following study was to assess the role of DW-MRI with calculation of the ADC in characterizing benign and malignant breast lesions.

2. Patients and methods

2.1. Patients

Thirty-nine female patients with breast masses of various BIRADS grading (BIRADS 2–5) detected in sonomammography were included in this prospective study. Only simple cystic lesions of the breast were excluded from the study. All the included patients had no contraindications for MRI examination. Pathological tissue proof was obtained from the detected lesions in all cases.

This prospective study was conducted in the Radiology Department of Assiut University Hospitals during the period from July 2014 through August 2015, after approval of the institutional board of ethics. An informed consent was obtained from each patient. A brief explanation of the examination technique was given to every patient, including clear instructions of avoiding unnecessary movement during MRI examination.

2.2. MRI technique

All patients included in the study have been initially evaluated by mammography and breast ultrasound beforehand breast MRI study. MRI examinations have been performed using a 16-channels 1.5 Tesla MRI system (Achieva, Philips Medical Systems, Best, The Netherlands). A dedicated 4-channel phased-array breast coil was used in all cases with two recesses allowing simultaneous examination of both breasts. The patients were examined in the prone head-first position with arms by the sides of the body.

The examination protocol consisted as a standard of conventional pulse sequences, EPI-DWI and dynamic contrast enhanced (DCE-MRI). An initial T1W-FFE (fast-field gradient-echo) multi-planar localizer was obtained, followed by a brief coil sensitivity calibration scan (reference scan) prior to performing the pulse sequences. This pre-processing reference scan provides coil uniformity corrections that allow application of the CLEAR (Constant Level Appearance) option during subsequent scanning to obtain clear reconstruction with higher signal to noise ratio (SNR). The applied pulse sequences included;

1. **Axial T1W** (FOV 410 × 250, TR/TE, 542/13 ms; slice thickness, 3 mm; matrix, 340 × 512, NSA 2).
2. **Axial T2W** (FOV 410 × 250, TR/TE, 3700/120 ms; slice thickness, 3 mm; matrix, 340 × 512, NSA 2).
3. **Axial fat-suppressed T2W** "**T2W-SPIR**" (FOV 410 × 250, TR/TE, 4180/72 ms; slice thickness, 3 mm; matrix, 340 × 512, NSA 2).
4. **Axial EPI-DW,** a two-dimensional echo-planar imaging (EPI) sequence (TR/TE, 8200/95 m sec; flip angle, 90°; slice thickness, 3.5 mm; matrix, 192 × 192; signal averages 4) in the axial plane. The sensitizing diffusion gradients were used in the three orthogonal planes with different $\boldsymbol{b}$ values ($\boldsymbol{b}$ = 0, 200, 400, 600 and 800 m sec/mm^2). The obtained diffusion series were routinely registered before creating the corresponding ADC maps.
5. Axial **three-dimensional (3D) dynamic fat-suppressed (T1 High-Resolution Isotropic Volumetric Excitation) (THRIVE)** (FOV 410 × 250, TR/TE, 476/10 ms; flip angle 10°; 150 slices, matrix 320 × 512, NSA 2, fat suppression SPAIR) with bolus injection of intravenous gadolinium-based contrast (Magnevist, Schering, Germany) at a dose of 0.1 m mol/kg body weight using an MR-compatible dual-head automatic injector at a rate of 4 ml/s, followed by 20 ml saline flush at the same rate. The dynamic contrast-enhanced study consisted of six consecutive repetitions, each lasting for 56 s. Subtraction of the contrast-enhanced dynamic images was done routinely.
6. Sagittal **STIR** (FOV 410 × 250, TR/ TE/TI, 8000/70/170 ms; echo train length, 12; 24 slices, thickness, 3 mm; gap, 1 mm; matrix 240 × 256).

2.3. Analysis of the obtained images

The obtained MR images were transferred to a post-processing workstation (Extended Workspace R2.6.3.1, Philips Medical Systems, Best, The Netherlands) for visualization, analysis and post-processing.

Conventional images were analyzed first, and any identified suspicious lesions were characterized and documented. The enhancement pattern of the detected lesions was analyzed objectively by the creation of time-intensity curve. The lesions were then identified in the corresponding slices of DW images.

For measurement of the ADC value, a region-of-interest (ROI) was drawn overlying the lesion in the ADC map generated from registered DW images. The mean ADC value within the selected ROI (multiplied by 10^{-3}mm^2/sec) was measured and documented for each lesion. ADC ROIs were defined using a small fixed area of 10 mm^2. On application of ROIs, areas of hemorrhage or necrosis were avoided as possible. The mean ADC value was calculated with large lesions exhibiting multiple ADC readings.

All MR examinations were done before performing the biopsy