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Original article

The Impact of DWI as a Complimentary Tool to Conventional MRI in Evaluation and Differentiation between Recurrent Breast Tumor and Surgical Scar

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Abstract

Background: Breast MRI plays an increasingly important role after breast conservative therapy due to its high contrast resolution, lack of ionizing radiation and possibility of performing functional imaging sequences. DWI can now be used in breast imaging with an improved image quality and enables qualitative and quantitative assessment of tissue diffusivity. This study aimed to assess the impact of diffusion-weighted images as a complementary tool to conventional breast MRI in the evaluation and differentiation between recurrent tumor and surgical scar. **Methods:** The current study included 37 consecutive women who had surgery for breast cancer and referred for breast MRI for workup of a suspicious clinical, mammographic, or sonographic abnormality. The study was conducted in Benha hospital during the period from July 2021 to July 2022. Cases were referred from general surgery departments in Benha hospital. The patients underwent full history taking and clinical examination. **Results:** The combination of DWI to contrast-enhanced-MRI could show high diagnostic value in the evaluation of scar in patients operated for breast cancer. The combination of DWI and contrast-enhanced- MRI could reveal high diagnostic accuracy in the suspect of local recurrence of breast cancer. **Conclusion**: DWI improves the diagnostic accuracy of the DCE-MRI of the breast. It is a better method for detection than either T1- or T2-weighted imaging, but it is better to be performed in conjunction with contrast enhanced MRI.

Keywords: DWI; complimentary tool; conventional MRI; recurrent breast tumor**;** surgical scar

Introduction

Imaging of the breast is a vital component, not only for breast cancer screening, but also for diagnosis, evaluation, treatment, and follows up of the patients with any breast lesion (**1)**.

Mammography is the main investigation for imaging of the breast cancer. Full field digital mammography is superior to standard mammography especially in women with dense breast but mammographic images are usually not enough to determine the existence of benign or malignant disease and the radiologist in some circumstances recommend further diagnostic tools **(1)**.

Magnetic resonance imaging (MRI) can discriminate benign from malignant lesions. Contrast enhanced MRI study of the breast is based on the enhancement pattern of the lesions and morphologic changes, with these two criteria breast MRI has a sensitivity of about 85-99 % in detecting malignant breast lesions. However, there is an overlap of these criteria with benign lesions which leads to a reported specificity of about 40 to 80 % **(2).**

Nowadays, there is increasing number of published studies, which mentioned that the specificity of the breast MRI could be increased by using diffusion –weighted imaging (DWI) **(2).**

DWI is a technique that involves the exchange of water molecules (diffusion) between breast tissue compartments. Diffusion rates vary between normal and pathologic tissues. The value of diffusion of water in tissues is called apparent diffusion coefficient (ADC) and it is calculated in the MRI machine by using (ADC) mapping. The studies showed that the ADC vary between malignant and benign breast masses. So application of DW sequence to the breast MRI will improve the specificity of the MRI, and can help to save the women from unnecessary breast biopsies (**3)**.

Also this principal of changes occurring in water mobility measured by diffusion MRI can predict the very early response of the breast cancer to chemotherapy before frank changes of tumor volume are significant **(4)**.

Recent meta-analyses have demonstrated that combining diffusion-weighted imaging (DWI) with standard dynamic contrast enhanced MRI (DCE-MRI) results in an improvement of specificity from 72% using DCE-MRI alone to 85% with the addition of DWI. Improving specificity in evaluating lesions can reduce the number of false-positive results and hence unnecessary biopsies. DWI shows potential to distinguish malignant from benign tissues, differentiate post treatment changes from recurrent tumour and provide a biomarker of response to chemotherapy prior to any change in size **(5)**.

MRI is not indicated in the routine follow-up of breast cancer as most relapses are either detected clinically or by conventional breast imaging. MRI is of value in cases where there is difficulty in distinguishing between surgical scarring and recurrent disease. The majority of scars more than 6 months old do not enhance significantly, while all malignancies will generally show enhancement **(6).**

This study aimed to assess the impact of diffusion-weighted images as a complementary tool to conventional breast MRI in the evaluation and differentiation between recurrent tumor and surgical scar.

Patients and methods

The current study included 37 consecutive women, who had surgery for breast cancer and were referred for breast MRI for workup of a suspicious clinical, mammographic, or sonographic abnormality. The study was approved by the local ethical committee.

This cohort study was conducted in Department of Radiodiagnosis, Faculty of Medicine , Benha University during the period from July 2021 to July 2022. Cases were referred from general surgery departments in Banha hospital. The patients underwent full history taking and clinical examination.

MR imaging protocol

Dynamic contrast enhanced MRI was performed with high field strength 1.5 Tesla on Signa system (Philips Intera) using dedicated double breast coil.

Coronal T1 weighted spin echo sequence was carried out for localization purpose and followed by plain sequences using T1weighted fast spin echo sequence (TR=501 msec.,TE=10 msec.),in addition to T2 weighted fast spin echo sequence (TR=4131mesc.,TE=120msec.) in axial orientation

DWI was performed before the DCE-MRI acquisition using a diffusion-weighted echo-planar imaging (EPI) sequence with parallel imaging (Philips Intera); reduction factor, 2; 7,000/71.5; number of excitations, 2; matrix, 240 × 240; field of view, 34 cm; slice thickness, 3 mm; and gap, 0. Diffusion gradients were applied in six directions with b

= 0, and 800 s/mm^2, and the scanning time was 4 minutes. Respiratory triggering was used for better resolution.

A bolus of gadolinium dimeglumine (Gd-DTPA) (Magnavist,Schering AG Berlin,Germany) was injected manually intravenous at a dose of (0.1mmol/kg) followed by saline flush to ensure that contrast –enhanced images could be obtained immediately after contrast agent injection.

Dynamic T1 WIs then performed using Gradient echo T1 weighted image with fat suppression at the following time points: 1,27 minute, 2,55 min., 4,21 min.,5,47 min and 7,13 min.

Image post processing on the workstation:

Post processing image subtraction was obtained between the post contrast imaging showing maximum enhancement and pre-contrast images (in the same axial plane), using the software subtraction function available on the work station.

Diffusion maps were formed. A noise-level threshold of 200 was applied to mask the b = 0 s/mm^2 images before forming diffusion maps. ADC maps were obtained from the diffusion weighted images by $ADC = -\frac{1}{b}\ln\left(\frac{S_{DWI}}{S_0}\right)$ where S_{DWI} is the combined DWI (geometric average of individual b = 800 s/mm^2 diffusion-weighted images), and S_0 is the b = 0 s/mm^2 reference image.

An ROI was defined for each DCE-MRI–detected lesion at the corresponding location on the combined DWI (S_{DWI}) series. The mean ADC of the voxels in the ROI was calculated for each lesion. Quantitative analysis was done by placing the ROI at the most enhanced part within the lesion result in automatically created time/ signal intensity curve.

MRI image interpretation

Subtraction images were first examined to detect the presence or absence of lesion enhancement.

In case of lesion enhancement the corresponding non subtracted pre-contrast and post contrast images in each time point was viewed together and lesions interpretation took place whether it a focus, mass or surgical scar.

In case of recurrent mass enhancement evaluation was carried out as follow:

- Its shape (regular or irregular).

- Its border (well defined, ill defined, speculated).
- Pattern of enhancement (homogenous, heterogeneous or ring enhancement).

Diffusion – weighted images and ADC maps are then examined regarding the signal intensity and the mean ADC of each lesion.

Data analysis

Data were statistically described in terms of range, mean ± standard deviation (± SD), frequencies (number of cases) and percentages when appropriate. Accuracy was represented using the terms sensitivity and specificity. All statistical calculations were done using computer programs Microsoft Excel 2003 (Microsoft Corporation, NY, and USA) and SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 15 for Microsoft Windows.

Results

In all 37 patients, we measure the ADC value of the index lesion. The median ADC of malignant lesions and benign lesions was 0.81 $\times$ 10−3 mm^2/s and t 1.2×10−3 mm^2/s respectively. ADC values were significantly lower in malignant compared with benign lesions ($p < 0.001$) (**Table 1 & fig. 1).**

The resulting sensitivity and specificity of DWI were 66.7% and 96% respectively**.** The combined MRI protocol of DCEMRI and DWI was true-positive in 6 and true-negative in 27 patients. There were no false-negative cases. However, there were four false-positive cases. The histopathological diagnoses of these false-positive cases were abscess (**Table 2,3 & fig.2).**

Case presentation

Forty eight years old female, underwent left breast lumpectomy.

A- Axial T1W show left breast central irregular speculated lesion underlying the operative bed with low signal intensity.

B- Axial T2W STIR show left breast central irregular speculated lesion underlying the operative bed with low signal intensity other nearby high signal intensity.

C- Axial dynamic THRIVE sequence & T1 +C Time/signal intensity analysis of ROI. The left breast lower central lesion shows progressively rising curve pattern (Type I) with SI % of 98 %.

D- Axial T1W +C no significant enhancement.

E- Diffusion sequence b0 showing no restricted diffusion.

F- Diffusion sequence b800 showing no restricted diffusion of the left breast two central lesions.

G- ADC map. ADC value for ROI was 2 $x10^{-3}$ mm^{2}/s.

According to multiparametric MRI protocol based on morphological, enhancement pattern and dynamic time intensity curves goes with fibrosis. According to diffusion weighted image data and high ADC value the lesion most likely fibrosis.

Pathology: Post operative scar tissue and seroma (**Fig. 3).**

Discussion

Adding an ADC threshold to the breast MRI assessment, increased the PPV over DCE-MRI alone and would have prevented biopsy for many benign lesions. This improvement in PPV by DWI was not found to be limited by lesion type or size **(7).**

In addition, using DWI & ADC values are reportedly useful in differentiating scar tissue from recurrence lesions and in the detection of breast cancer without administration of contrast medium. Hence, DWI could be a promising tool in screening for breast post management without using contrast medium, especially for patients with renal dysfunction or previous reactions to contrast agents and will relieve the cost of examination **(8).**

The perfusion effect is seen when a b value of less than 400 s/mm2 is used **(9).**

So, to get rid of perfusion effect and hence the ADCs obtained with the use of high b values is more effective for differentiation of malignant from benign tumors, we used b-value of 800 s/mm^2.

Low spatial resolution is one of the limitations of diffusion-weighted imaging. Small cancer foci, including DCIS and scattered foci of invasive lobular cancer, may not be depicted at diffusion-weighted imaging.

The higher SNR afforded by imagers with higher magnetic field strength can be used to increase the spatial resolution of diffusion-weighted imaging, thereby allowing the detection and characterization of smaller lesions.

Consistent with these studies, recurrence lesions revealed significantly lower ADC values than scar tissue in our study. The mean of ADC was 0.81 and $1.2 \times 10{-}3$ mm^2/s, respectively.

Another study ***(10)*, stated that** a total of 126 breast lesions were detected. Pathology results revealed 100 malignant and 26 benign lesions. Mean diameter of lesions was 26.02 mm (range 4 –90 mm), including 52 lesions ≤15 mm in size. Mean ADC value of normal glandular tissue was 1.55×10−3mm2/s. Mean ADC value of malignant lesions was 0.97×10−3mm2/s. Mean ADC value for benign lesions was 1.66×10− 3mm^2/s. Benign lesions showed ADC values significantly higher than malignant lesions **(10).**

These distributions have resulted in a recommended ADC cut-off value ranging from 1.1 to 1.6 × 10-3 mm^2/s between malignant and benign lesions **(11).**

The observed increased enhancement within the tumors (compared with normal breast tissue) is presumably caused by the increased vascularity and vascular permeability. The majority of scars more than 6 months postoperatively do not enhance significantly while all malignancies enhance significantly **(12)**.

The combined MRI protocol of our study, which consisted of DCE-MRI and DWI, provided 83% sensitivity, 92.3% specificity and 88.9% accuracy in the diagnosis of breast cancer, and the addition of DWI to DCE-MRI improved the specificity of breast MRI from 88.4% for DCE –MRI alone to 92.3% for combined DCE-MRI and DWI protocols.

These results agree with recent published study **(13), that** documented the combination of DCE-MRI with DWI. They stated that it provided 95.7% sensitivity and 89.2% specificity, and the specificity of breast MRI improved by 13.5% without a significant decrease in the sensitivity.

Another study **(14),** showed that the combination of the ADC value criteria with the analysis of DCE-MRI pattern improve the sensitivity and the accuracy of conventional breast MRI. It increases the sensitivity to 93.3%, negative predictive value to 85.7% and accuracy to 77.8% (while the sensitivity, NPV, and accuracy for DCE –MRI alone were 68.8%, 58.3%, and 66.7% respectively).

The combined MRI protocol of DCE-MRI and DWI was true-positive in 6 patients, true-negative (no areas of suspicious enhancement) in 28 patients. There were no false-negative cases. However, there were 3 false-positive cases. The histopathologic diagnoses of these false-positive cases were abscess.

Abscess has low ADC values similar to those of malignant tumors. The area of low ADC value within an abscess usually has high signal intensity on T2-weighted images, which indicates the high water content and high viscosity of the abscess. In clinical practice, physical examination findings should be considered when assessing these entities, thereby simplifying the radiologic diagnosis **(9).**

Yabuuchi et al.,( )found the best cut of value between the malignant and benign lesions around (0.9 × 10-3) mm2/s., and we think that all MRI sites should determine their own cutoff values according to the DWI sequence used for breast imaging**.**

Conclusion

DWI improves the diagnostic accuracy of the DCE-MRI of the breast. It is a better method for detection than either T1- or T2-weighted imaging, but it is better to be performed in conjunction with contrast enhanced MRI**.**

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