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ORIGINAL ARTICLE

Comparison of 3.0- and 1.5-tesla diffusion-weighted imaging in the visibility of breast cancer

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Abstract
Purpose. The aim of this study was to compare diffusion-weighted imaging (DWI) at 3.0 T and 1.5 T by evaluating the apparent diffusion coefficient (ADC) value and visibility of breast cancer in the same patients.
Materials and methods. A total of 13 patients (16 lesions) with breast cancer underwent DWI at 3.0 T and 1.5 T. Tumors were classified into two groups based on the lesion size. The ADC values were measured, and visibility of the tumors was scored blindly.
Results. No significant difference was found for ADC values between 3.0 T and 1.5 T in either group ($P > 0.05$). All of the large lesions were visible clearly at both magnetic field strengths, and image scores were not different ($P > 0.05$). In contrast, small lesions were more clearly visible and had better image scores at 3.0 T than at 1.5 T ($P < 0.001$).
Conclusion. Small cancers were more clearly visible on DWI at 3.0 T than 1.5 T.

Key words 3.0 Tesla · Diffusion-weighted imaging · Breast cancer

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Introduction

Breast cancer is a common disease among women. Mammography and ultrasonography (US) are widely used for early detection and to determine the extent of the cancer; however, in some women, breast tissue is dense and prevents detection of cancer. There has been great interest in magnetic resonance imaging (MRI) as a modality for the detection of cancer and assessment of the extent of invasion because its sensitivity is not influenced by tissue density. Previous studies reported that MRI enabled the detection of breast cancer that was occult on mammography and US.[1–7]

Recently, diffusion-weighted imaging (DWI) has been applied increasingly to the body as well the central nervous system. DWI of the breast is expected to have clinical potential because of its high sensitivity.[8–12] 3.0-T MR scanners are widely used clinically and provide a higher signal-to-noise-ratio (SNR) and greater spatial resolution than 1.5-T scanners. For example, in prostate tissue it is said that DW images obtained at 3.0 T provides superior morphological details of the prostate than that obtained at 1.5 T because of the higher SNR.[13]

The purpose of the present study was to compare DWI at 3.0 T and 1.5 T by evaluating the apparent diffusion coefficient (ADC) value and the visibility of breast cancer on DWI in the same patients.

Materials and methods

Subjects

A total of 13 contiguous patients (16 lesions) with breast cancer underwent breast MRI, including DWI at 3.0 T and 1.5 T. All of the patients were women, and ages ranged from 31 to 69 years (mean 56 years). The pathological diagnosis was obtained in all patients after surgical resection or needle biopsy and revealed five ductal carcinoma in situ (DCIS), three scirrhous carcinomas, five solid-tubular carcinomas, one papillotubular carcinoma, one invasive micropapillary carcinoma, and one intracystic papillary adenocarcinoma. One lesion was a recurrence of bilateral duplicated breast cancer detected in the right breast after treatment. Two lesions in one patient represented a recurrence following mastectomy for left-side breast cancer.

The lesions were classified into two groups based on the lesion size (group A > 10 mm; group B ≤ 10 mm). Lesion size was defined as the longest diameter on the early stage of dynamic contrast-enhanced study, which was performed using a 1.5-T scanner. The dynamic study consisted of three-dimensional fast spoiled gradient-recalled echo (3DFSPGR) sequence (TR 5.8 ms; TE 2.8 ms; FOV 35 × 35 cm; MTX 320 × 320; slice thickness 2 mm; NEX 1) after a bolus injection of gadolinium-diethylenetriamine pentaacetic acid (Gd-DTPA). The mean sizes of the lesions detected on MRI were 17 mm (range 13–24 mm) in group A (seven lesions) and 6.4 mm (range 3–10 mm) in group B (nine lesions). The protocol was approved by the Ethics Review Board, and written informed consent was obtained from all subjects.

MRI

Measurements were performed using a 3.0-T Signa Excite and a 1.5-T Signa Excite HD (GE Medical Systems, Milwaukee, WI, USA). In the 3.0-T system, images were obtained using two 7-inch handmade circular coils and the following parameters: TR 6000 ms; TE 59 ms; FOV 40 × 40 cm; MTX 128 × 192; slice thickness 3 mm; NEX 4; acquisition time 192 s. In the 1.5-T system, images were obtained using an open breast-array coil with the following parameters: TR 6000 ms; TE 66 ms; FOV 33 × 33 cm; MTX 128 × 192; slice thickness 5 mm; NEX 4; acquisition time 96 s. Our slice thickness at 3.0 T was thinner than that at 1.5 T to increase slice resolution, but the FOV was a little large at 3.0 T to prevent distortion of DWI in comparison with that at 1.5 T. We used the array spatial-sensitivity encoding technique (ASSET) in both scanners after initial localizing scans. Diffusion-weighted (DW) images at 1.5 T were acquired after a dynamic contrast-enhanced study, and then DW images at 3.0 T were acquired. DWI was performed at b-values of 1000 s/mm^2 for both scanners.

Diffusion-weighted images analysis

ADC values were calculated according to the following formula

$$ADC = -(1/b)\ln [S(b)/S(0)]$$

where ln is the natural log, and S(0) and S(b) are the signal intensities in the region of interest (ROI) placed on sections that correspond to two different b factors (b = 0 and 1000 s/mm^2). For each patient, images were acquired at 3.0 T and 1.5 T. To obtain the ADC values of the lesions, ROIs were placed carefully within the enhanced portions of the tumors, avoiding necrotic regions, guided by information from 3DFSPGR imaging following administration of Gd-DTPA. The sizes of the ROIs were set the same at 3.0 T and 1.5 T. The ADC values at 3.0 T and 1.5 T were calculated and compared.

One radiologist with 6 years' experience in MRI diagnosis set the background window level of DW images apparently indistinct between 3.0 T and 1.5 T images, with the window width two times the adjusted window level. The radiologist then chose one slice for each of the adjusted DW images in which tumor was the most clearly visible.

Another four radiologists (3–8 years' experience in MRI diagnosis) visually evaluated the selected DW images and assigned each an image score on a scale of 1–5: 1, tumor is not visible; 2, tumor is visible as a slight change in signal; 3, tumor is visible; 4, tumor is distinctly visible; 5, tumor is distinctly visible with a definite border. Image evaluation was performed blindly, with no information supplied regarding patient details or the field strength in which the images were acquired. Image scores of each DW image evaluated by four radiologists were averaged and compared at both magnetic field strengths in either group.

Student's *t*-test was used for statistical analysis when comparing the ADC values and image scores of breast cancer for images acquired at 3.0 T and 1.5 T for groups A and B. Differences in the ADC values and image scores were considered statistically significant for $P < 0.05$.

Results

For the large lesions (group A > 10 mm), mean ADC values for breast cancer were $0.98 \pm 0.16 \times 10^{-3}$ mm^2/s at

3.0 T and $0.95 \pm 0.29 \times 10^{-3}$ mm^2/s at 1.5 T (Fig. 1). For the small lesions (group B ≤ 10 mm), they were $1.13 \pm 0.22 \times 10^{-3}$ mm^2/s at 3.0 T and $1.18 \pm 0.26 \times 10^{-3}$ mm^2/s at 1.5 T (Fig. 2). No significant difference was found for ADC values between 3.0 T and 1.5 T in either group ($P > 0.05$).

Large lesions (group A > 10 mm) were visible clearly at both strengths (Fig. 3). Image scores for these lesions were slightly higher at 3.0 T than 1.5 T, but there was no statistically significant difference between the two field strengths ($P > 0.05$) (Fig. 4). In contrast, small lesions (group B ≤ 10 mm) were visible more clearly at 3.0 T (Figs. 5–7), and image scores were higher at 3.0 T than at 1.5 T; these results were statistically significant ($P < 0.001$) (Fig. 8).

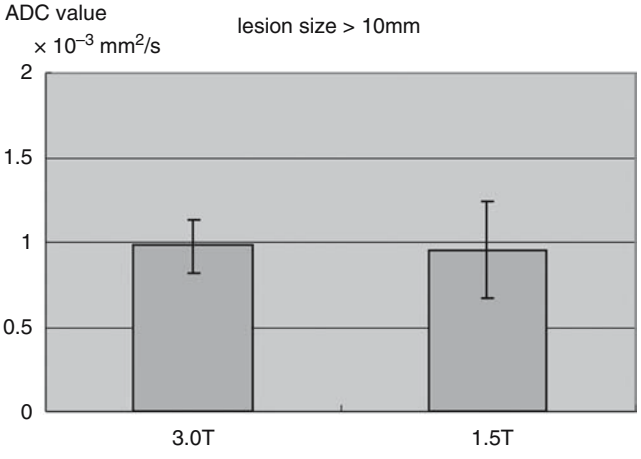

Fig. 1. Comparison of the apparent diffusion coefficient (ADC) values between 3.0 T and 1.5 T in large lesions (group A, >10 mm). No significant difference was found for ADC values between 3.0 T and 1.5 T ($P > 0.05$)

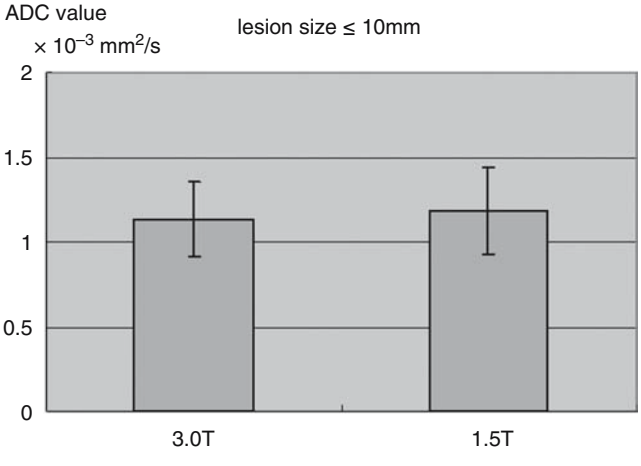

Fig. 2. Comparison of the ADC values between 3.0 T and 1.5 T in small lesions (group B ≤ 10 mm). No significant difference was found for ADC values between 3.0 T and 1.5 T ($P > 0.05$)

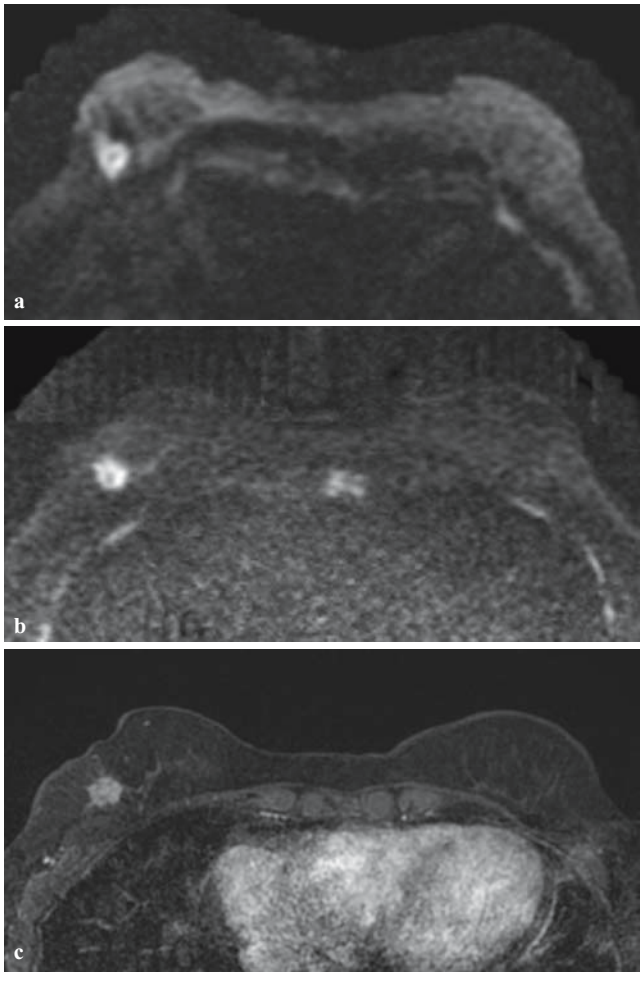

Fig. 3. a, b Diffusion-weighted images obtained at (**a**) 3.0 T and (**b**) 1.5 T. **c** Three-dimensional fast spoiled gradient-recalled-echo (3DFSPGR) imaging with gadolinium-diethylenetriamine pentaacetic acid (Gd-DTPA). The 14-mm lesion is visible clearly on images obtained at both 3.0 T and 1.5 T

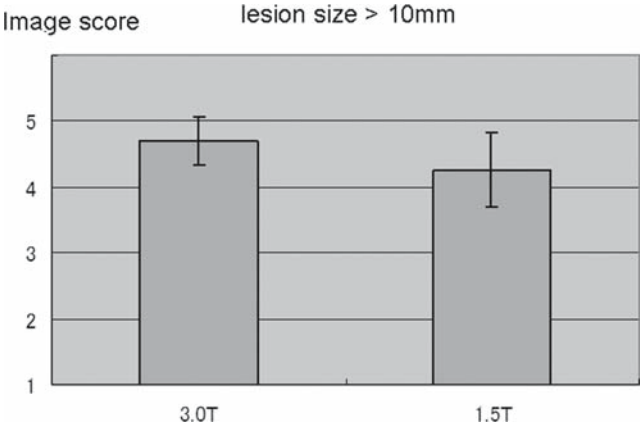

Fig. 4. Image scores for group A (>10 mm). Lesions are visible clearly at both 3.0 T and 1.5 T

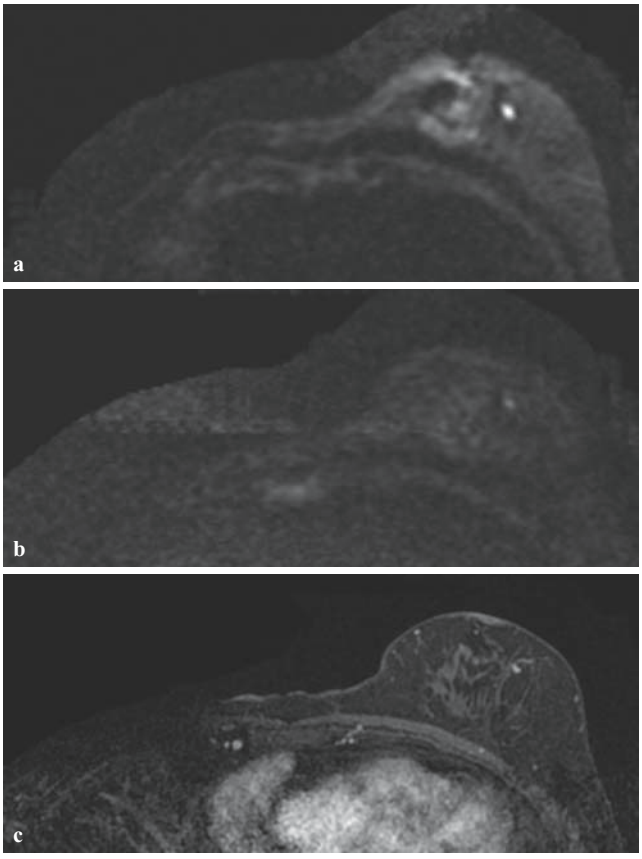

Fig. 5. a, b Diffusion-weighted images obtained (**a**) 3.0 T and (**b**) 1.5 T. **c** 3DFSPGR imaging with Gd-DTPA. A 61-year-old woman with a recurrence of bilateral duplicated breast cancer in the right breast after treatment. The 3-mm lesion is visible on diffusion-weighted images obtained at 3.0 T but appears only as a slight signal change at 1.5 T

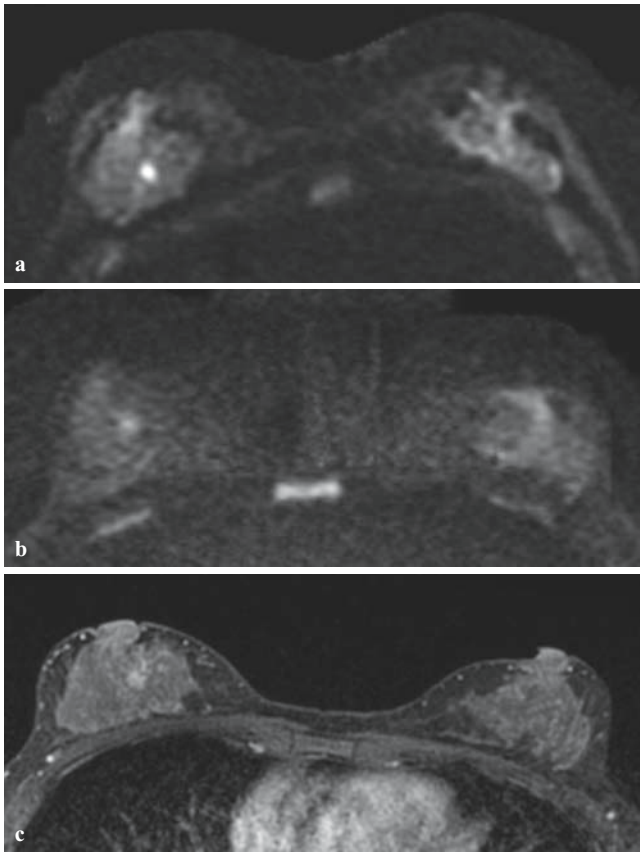

Fig. 6. a, b Diffusion-weighted images obtained at (**a**) 3.0 T and (**b**) 1.5 T. **c** 3DFSPGR imaging with Gd-DTPA. The 6-mm lesion is visible more clearly at 3.0 T than at 1.5 T

Discussion

Magnetic resonance imaging of the breast, especially with the use of contrast material, is an important tool in the investigation and management of breast cancer. It has been suggested that MRI is useful for: (1) detecting cancers that are occult clinically and mammographically; (2) assessing lesion size and spread; and (3) differentiating between malignant and benign lesions.[1–7]

Diffusion-weighted imaging has become a common investigation tool and is used extensively in the central nervous system (e.g., for the diagnosis of acute cerebral infarction).[14,15] Recently, DWI has been increasingly applied to breast imaging following development of the parallel imaging technique.[10] According to some reports, the ADC values of breast lesions have advantages in differentiating between benign and malignant lesions and in evaluating the extension of tumor invasion; it is expected be a useful screening tool because of its short scan time and high sensitivity.[8,9,11] DWI is potentially useful also for assessing response to treatment at an earlier stage than is possible using tumor size measurements.[12]

3.0-T scanners are widely used in clinical practice. 3.0-T DWI provides a higher SNR and greater spatial resolution than 1.5-T DWI; however, higher magnetic strengths are accompanied by an increase in susceptibility artifact and nonuniformity in the magnetic field, causing image distortions. With parallel imaging techniques, these artifacts are prevented or at least significantly reduced, and image quality is improved.[16,17]

In theory, the ADC value is assumed to be independent of magnetic field strength. This view is supported by the results of the present study, which revealed no significant difference in the ADC values of the two magnetic field strengths in either group.

Small cancers (≤10 mm) were visible more clearly at 3.0 T than at 1.5 T. This suggests that DWI at 3.0 T is more helpful for detecting small cancers. Further investigations should focus on the selection of an appropriate b value and improvements in coil quality.

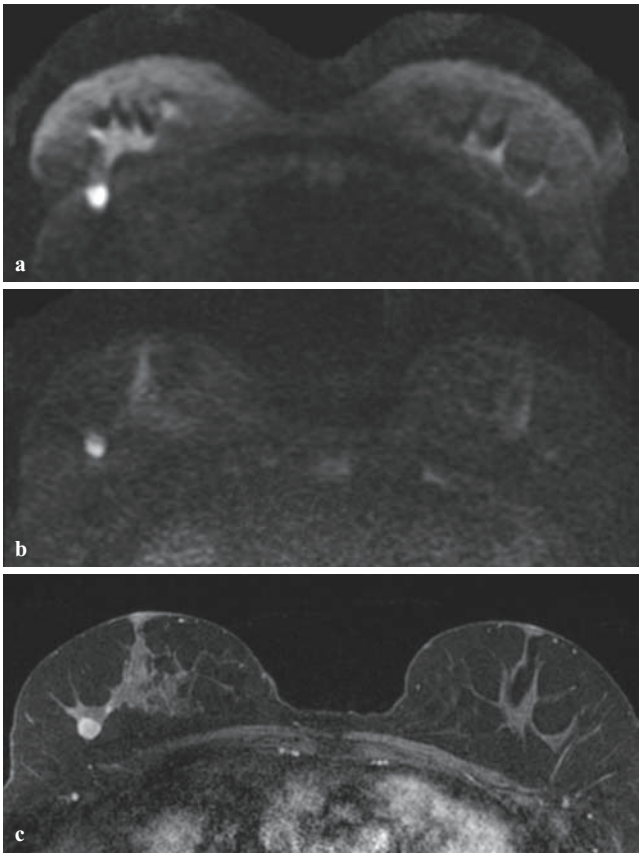

Fig. 7. a, b Diffusion-weighted images obtained at (**a**) 3.0 T and (**b**) 1.5 T. **c** 3DFSPGR imaging with Gd-DTPA. The 10-mm lesion is visible more clearly at 3.0 T than at 1.5 T

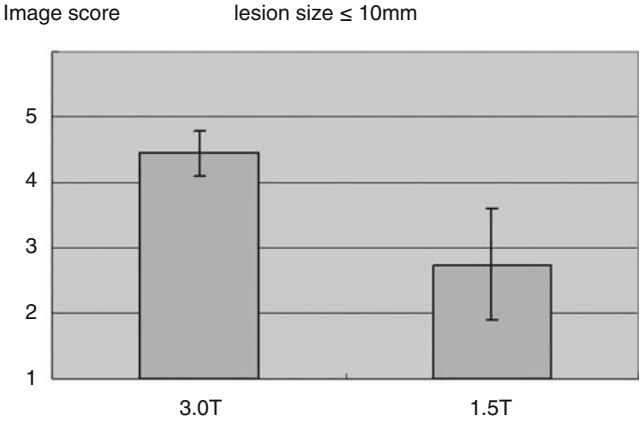

Fig. 8. Image scores for group B (≤10 mm). Lesions are visible more clearly at 3.0 T than at 1.5 T

Conclusion

No significant difference was found in the ADC value between field strengths of 3.0 T and 1.5 T. Small cancers were visible more clearly on DWI at 3.0 T than at 1.5 T. However, to clarify the usefulness of DWI at 3.0 T as a screening tool in comparison with DWI at 1.5 T, further study is required to investigate an appropriate b value using a greater number of subjects. Our results suggested that DWI at 3.0 T, compared to 1.5 T, would be a valuable adjunct in clinical routine examinations for breast cancer despite the increasing influence of susceptibility phenomenon.

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