Original Investigation

Diagnostic Usefulness of Combination of Diffusion-weighted Imaging and T2WI, Including Apparent Diffusion Coefficient in Breast Lesions: Assessment of Histologic Grade

Keum Won Kim, MD, PhD, Cherie M. Kuzmiak, DO, Young Joong Kim, MD, Jae Young Seo, MD, Hae Kyoung Jung, MD, Mu-Sik Lee, MD, PhD

Purpose: This study aimed to compare the diagnostic values of a combination of diffusion-weighted imaging and T2-weighted imaging (DWI-T2WI) with dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI), and to evaluate the correlation of DWI with the histologic grade in breast cancer.

Materials and Methods: This study evaluated a total of 169 breast lesions from 136 patients who underwent both DCE-MRI and DWI (b value, 1000s/mm^2). Morphologic and kinetic analyses for DCE-MRI were classified according to the Breast Imaging-Reporting and Data System. For the DWI-T2WI set, a DWI-T2WI score for lesion characterization that compared signal intensity of DWI and T2WI (benign: DWI-T2WI score of 1, 2; malignant: DWI-T2WI score of 3, 4, 5) was used. The diagnostic values of DCE-MRI, DWI-T2WI set, and combined assessment of DCE and DWI-T2WI were calculated.

Results: Of 169 breast lesions, 48 were benign and 121 were malignant (89 invasive ductal carcinoma, 24 ductal carcinoma in situ, 4 invasive lobular carcinoma, 4 mucinous carcinoma). The mean apparent diffusion coefficient (ADC) of invasive ductal carcinoma ($0.92 \pm 0.19 \times 10^{-3}$ mm^2/s) and ductal carcinoma in situ ($1.11 \pm 0.13 \times 10^{-3}$ mm^2/s) was significantly lower than the value seen in benign lesions ($1.36 \pm 0.22 \times 10^{-3}$ mm^2/s). The specificity, positive predictive value (PPV), and accuracy of DWI-T2WI set and combined assessment of DCE and DWI-T2WI (specificity, 87.5% and 91.7%; PPV, 94.3% and 96.2%; accuracy, Az = 0.876 and 0.922) were significantly higher than those of the DCE-MRI (specificity, 45.8%; PPV, 81.7%; accuracy, Az = 0.854; $P < .05$). A low ADC value and the presence of rim enhancement were associated with a higher histologic grade cancer ($P < .05$).

Conclusion: Combining DWI, T2WI, and ADC values provides increased accuracy for differentiation between benign and malignant lesions, compared with DCE-MRI. A lower ADC value was associated with a higher histologic grade cancer.

Key Words: Breast cancer; magnetic resonance imaging; diffusion-weighted imaging; apparent diffusion coefficient.

INTRODUCTION

Diffusion-weighted imaging (DWI) is currently being evaluated to increase the specificity of breast magnetic resonance imaging (MRI) (1–3). DWI is a noninvasive technique that uses the biological characteristics of Brownian movement of protons in water. High signal intensity (SI) on DWI and a low apparent diffusion coefficient (ADC) value are correlated with highly cellular tissue and decreased movement of molecules (4–7). When DWI is used, malignant breast lesions have higher SI than with T2-weighted imaging (T2WI) fast spin echo (FSE) MRI, and malignant breast lesions have low ADC values. Malignant breast

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From the Department of Radiology, Konyang University Hospital, College of Medicine, Myunggok Medical Research Center, Daejeon, Republic of Korea (K.W.K., Y.J.K., J.Y.S.); Department of Radiology, University of North Carolina, CB #7510, Physicians' Office Building, Rm #118, 170 Manning Drive, Chapel Hill, NC 27599 (C.M.K.); Department of Radiology, CHA Bundang Medical Center, CHA University, Seongnam (H.K.J.); Department of Preventive Medicine, Konyang University, College of Medicine, Daejeon, Republic of Korea (M.-S.L.). Received August 31, 2017; revised October 31, 2017; accepted November 10, 2017. **Address correspondence to:** C.M.K. e-mail: cherie_kuzmiak@med.unc.edu

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lesions display lower SI on T2WI than benign lesions because of shorter T2 relaxation time (8). The high cellularity of cancer cell caused the restriction of Brownian motion in extracellular water molecules around cancer cells. In contrast, fluid in cysts consists of free water molecules and a higher ADC (9,10).

Multiple studies have evaluated DWI and ADC value for breast tumor and evaluated the diagnostic value of combined dynamic contrast-enhanced (DCE) MRI and DWI for breast cancer detection (11–15). The detectability on DWI was higher than T1WI or T2WI for breast tumor, and the mean ADC value of invasive ductal carcinoma (IDC) and ductal carcinoma in situ (DCIS) were lower than benign breast lesions. Kul et al. revealed (11) the combination of DWI and DCE-MRI has the potential to increase the specificity of breast MRI. Another study reported that combined DCE-MRI and DWI had superior diagnostic accuracy than either DCE-MRI or DWI alone for the diagnosis of breast cancer (15). However, those studies did not compare each SI between DWI and T2WI for characterization of the lesion. In addition, those studies did not compare the accuracy of DWI-T2WI combination with that of DCE-MRI. In those studies, T2WI and DCE-MRI were used as pilot images for localizing the lesion. Thus, the purpose of our study is to compare the diagnostic values of a combination of DWI and T2WI with DCE-MRI, and to investigate the correlation of DWI, including ADC value, with the histologic grade in breast cancer lesions.

MATERIALS AND METHODS

Our institutional review board approved the study and waived patient informed consent because of the retrospective design. A total of 205 women with 230 breast lesions were initially included in this study. All included subjects underwent breast MRI between January 2011 and December 2015. There were 69 subjects with 61 lesions who did not have follow-up or histopathologic confirmation and were excluded from the study. Our final study population consisted of 136 women with 169 lesions (mean age, 48.6 years; range, 31–70 years). The diagnosis for all 169 lesions was confirmed by pathology. A total of 130 lesions (77%) were confirmed using surgically excised specimens: 45 (35%) modified radical mastectomy; 67 (51%) lumpectomy; 18 (14%) excisional biopsy. A total of 39 lesions (23%) were confirmed from a core needle biopsy specimen.

MRI Protocol

MRI examinations were performed using a 3.0 Tesla MRI system (Achieva 3.0T TX, Philips Medical Systems, Best, the Netherlands) and a breast coil (Philips, Sense breast coil 4ch 3.0T, Best, the Netherlands). To minimize the respiratory-motion artifact, the subjects were placed in the prone position and the imaging was performed. The protocols of each sequence of breast MRI are summarized in Table 1. This final scan was obtained before a rapid bolus injection of 0.1 mmol/kg of gadobutrol (Gadovist, Bayer Schering Pharma AG, Berlin, Germany). Scanning was repeated 1, 2, 3, 4, 5, 6, and 7 minutes after contrast administration. Subtraction images were obtained by subtracting the precontrast images from the postcontrast images on a pixel-by-pixel basis.

DWI Acquisition and ADC Analysis

The ADC was calculated according to the equation: ADC = (1/b2 − b1) ln (S2/S1), where S1 and S2 were the SIs in the regions of interest (ROIs) obtained using different gradient factors (b values of 0 and 1000 s/mm^2). For measuring the ADC value, two breast imaging radiologists, who were blinded to the results of the study, manually placed an ROI. When compared with DCE-MRI, the enhancing solid portion of the tumor was used to site the ADC measurement. The same radiologists reviewed images in consensus. An ROI at the corresponding location was manually defined on averaged DWI to include the area of hyperintensity. The

TABLE 1. Protocols of Each Sequence of Breast MRI

	Fat-suppressed Turbo Spin-echo (TSE-FS) T2WI	Postcontrast T1WI Fast Field Echo (T1WI-FFE)	DW Single-shot Echo-planar Imaging with Sensitivity Encoding (SENSE)
TR/TE	4375/70	4.4/1.6	1835/57
Flip angle	90°	10°	90°
Slices	30	270	30
Field of view	350 × 350 mm	340 × 340 mm	350 × 350 mm
Matrix	528 × 512	512 × 510	116 × 115
Number of excitation (NEX)	1.0	1.0	2.0
SENSE	1.5	2.0	0
Section thickness	4 mm	1.5 mm	4 mm
Intersection gap	0	0	0
Acquisition time	4 min	8 min	3 min
b Value			0 and 1000 s/mm^2

DW, diffusion-weighted; MRI, magnetic resonance imaging; TR/TE, repetition time/echo time; T1WI, T1-weighted imaging; T2WI, T2-weighted imaging.