

5 Lesion 3: T1-weighted image with ROI for dynamic analysis (A), subtraction image (B), dynamic curve (C) and ADC value (D).

Diffusion-Weighted Imaging for Characterizing Breast Lesions Prior to Biopsy

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Introduction

Diffusion-weighted imaging (DWI) is characterized by superior lesion to background contrast, and it has been applied in the brain e.g. to diagnose early-stage cerebral infarction. When used to image the body, however, strong artifacts are created by the non-uniformity of the magnetic field. Recent development of MR technology has nearly overcome this obstacle and enabled the clinical application of DWI. DWI has shown great promise in the detection of most tumor types throughout the entire body. Regarding breast DWI, the potential role of the apparent diffusion coefficient (ADC) in characterizing breast lesions has been reported. Preliminary results showed that ADC value may be an effective parameter for distinguishing between benign and malignant breast lesions because tumor cellularity has a significant influence on ADC values [1–3].

Optimal b-values

However, there is no international consensus in regard to the usefulness of DWI for breast cancer or the optimal b-values. Therefore, we perform categorization visually based on multi-b-factor DWI (500, 1000, 1500, 2000 and 3000 s/mm²), always applying the same window level and width. The significance of the five b-values at our institution is being investigated, particularly whether very high b-values of 2000 s/mm² or more might be useful for evaluating the effects of neoadjuvant chemotherapy. Currently, we routinely perform ADC calculations based on two b-values: 500 s/mm² and 1500 s/mm².

Interpretation of DWI: two-step evaluation for mass lesion

We previously reported the clinical usefulness of DWI using a two-step evaluation to detect rectal cancer [4]; we are testing a similar approach for breast

mass lesions. First, high b-value (b = 1500 s/mm²) images were assessed visually. Next, ADC values of mass lesions were calculated among the patients with positive results on DWI. The highest signal portion of the lesion was visually identified on original high b-value images, and a circular region of interest (ROI) was placed manually on that portion of the lesion. ADC values were calculated according to the equation

$$ADC \text{ (mm}^2\text{/s)} = 1/b_2 - b_1 \times \ln[IS(b_1)/IS(b_2)]$$

where IS(b₁) and IS(b₂) are the signal intensities resulting from two different gradient factors, b₁ = 500 and b₂ = 1500 s/mm².

At our institute, ADC measurements are not performed for non-mass type lesions because it is sometimes impossible to identify the highest signal portion at one location in the lesions.

Conclusion

DWI can be helpful to support diagnosis of cancerous breast lesions.

References

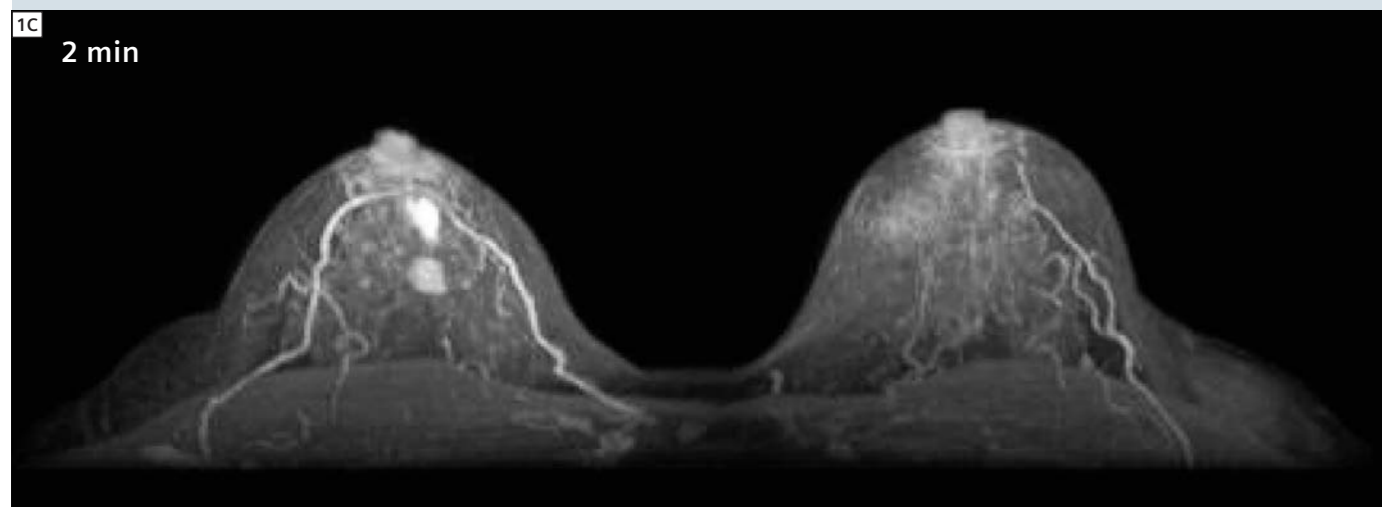
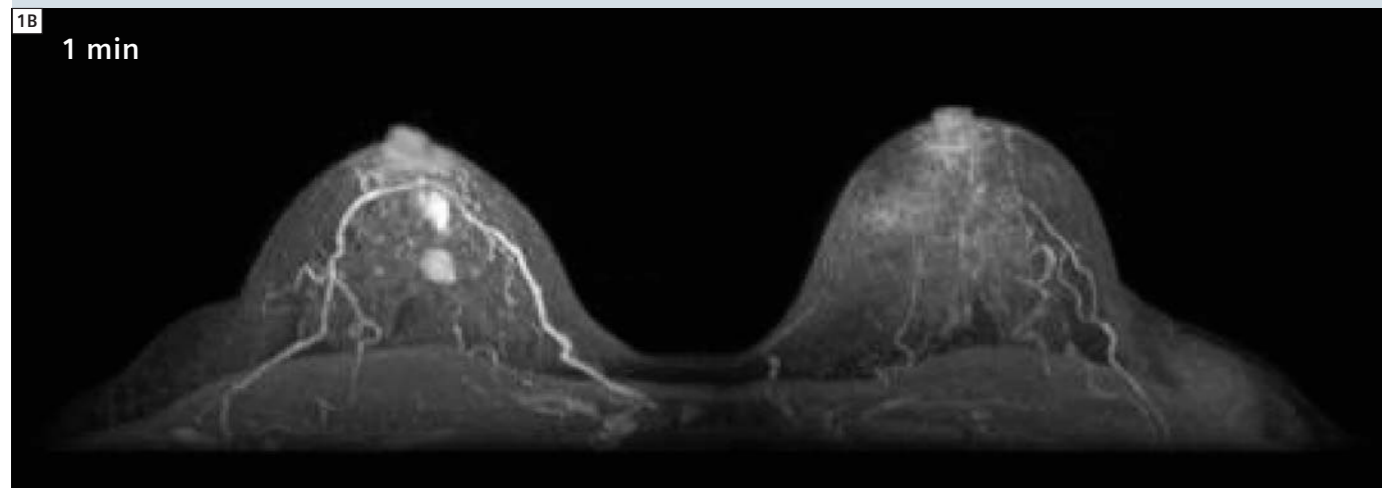
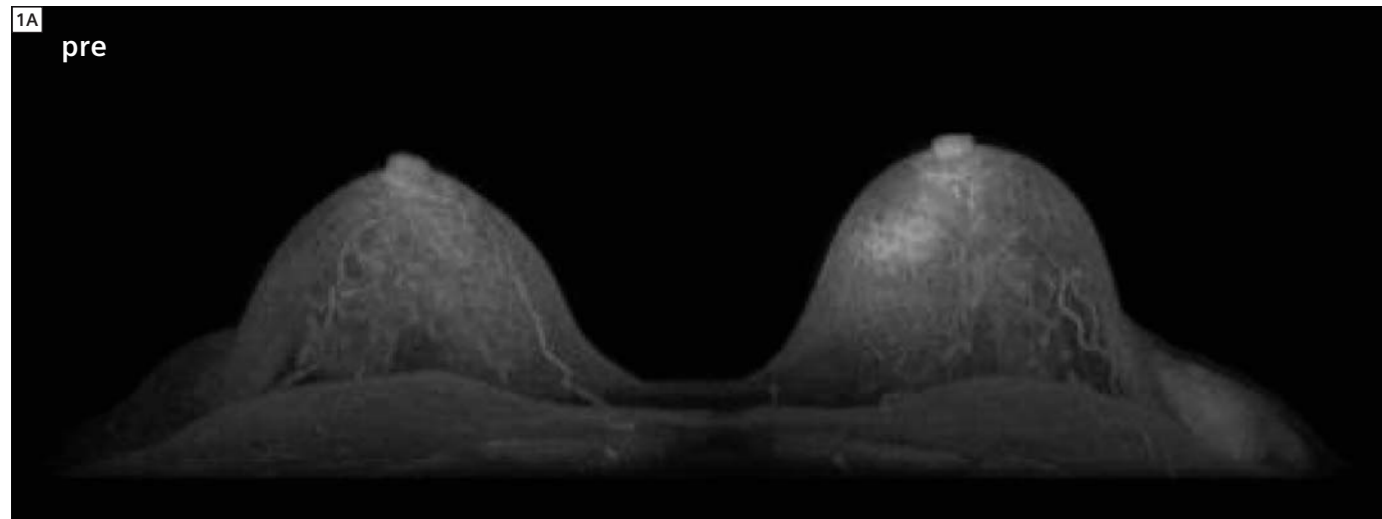
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1A-C Dynamic MRI sequence using VIBE with iPAT: Enhanced T1-weighted images with fat saturation show 2 irregular masses in the right breast.

Retrospective study for 171 breast lesions prior to biopsy

Patients

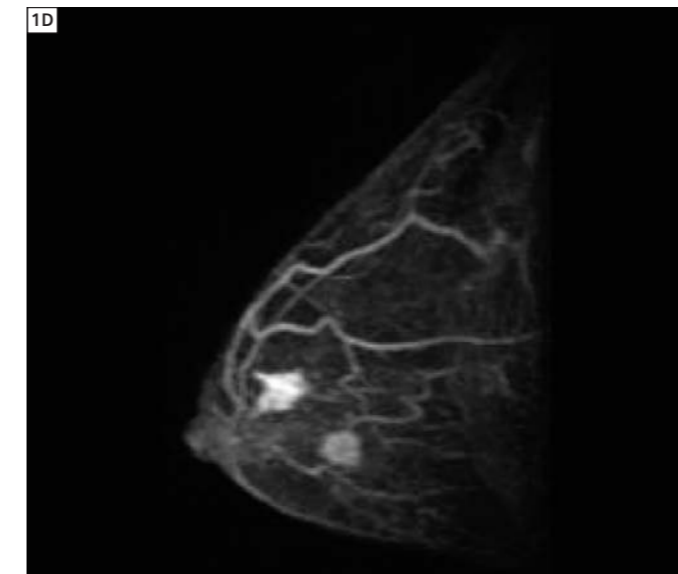
Between November 2007 and May 2008, breast MRI was performed for 1,486 patients with breast disease at our institute. Among them, 165 patients who had 171 suspicious or highly suspicious lesions classified as Breast Imaging Reporting and Data System (BI-RADS)-MRI category 4 (n = 112) or 5 (n = 59),

and who had a biopsy performed after MR examinations, were analyzed [5].

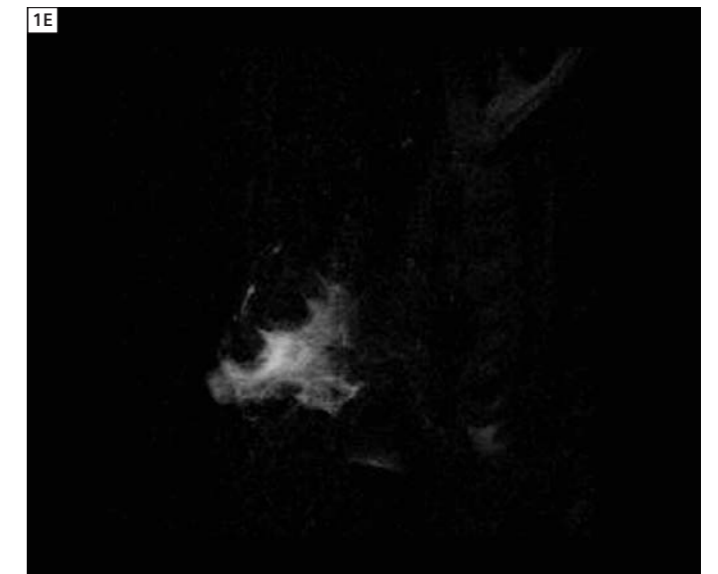
MR Sequences

MRI was performed using a 1.5 Tesla system (MAGNETOM Avanto; Siemens Healthcare, Erlangen, Germany) equipped with a double breast coil (Breast Matrix coil). Before applying dynamic sequences, bilateral sagittal fat-suppressed T2-weighted images and coronal

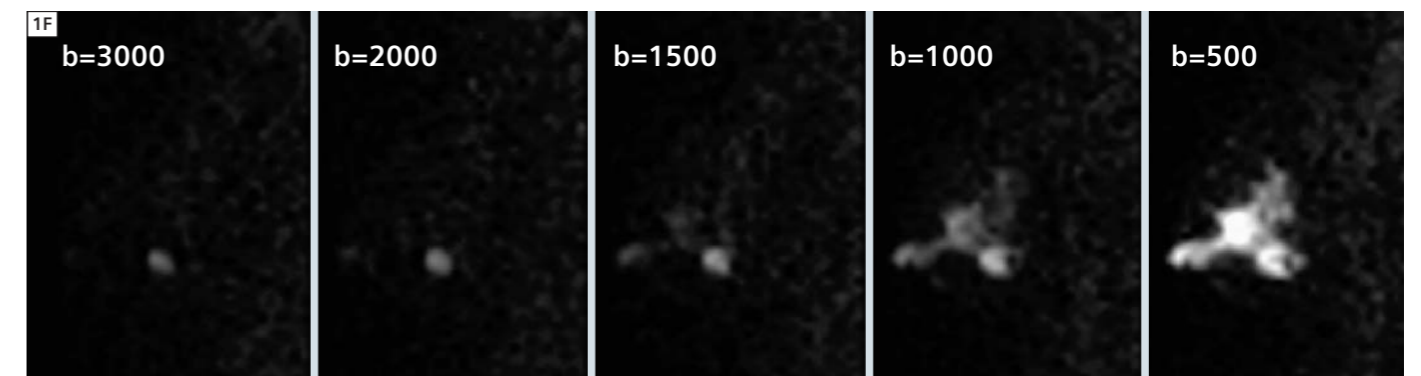
T1-weighted images were obtained. In addition, coronal diffusion-weighted images were acquired with a spin-echo-type single-shot echo-planar imaging sequence incorporating the *syngo* GRAPPA (generalized auto-calibrating partially parallel acquisition) algorithm for parallel acquisition. The parameters were as follows: TR/TE 8000/96 ms; field of view 33 cm; matrix 110 × 110; bandwidth 1684 Hz/Px; parallel acquisition factor 2; slice thickness 3 mm; acquisition time



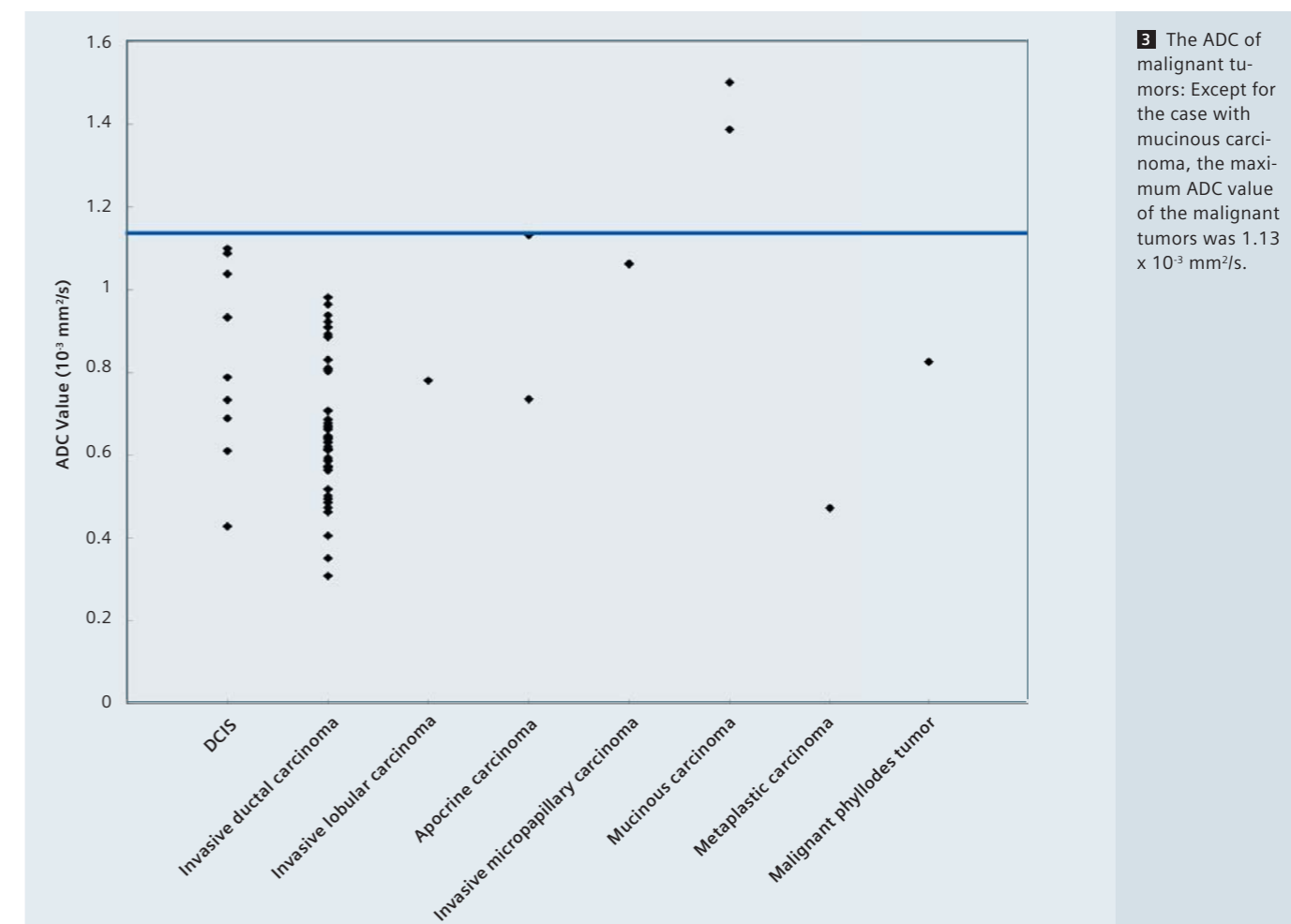
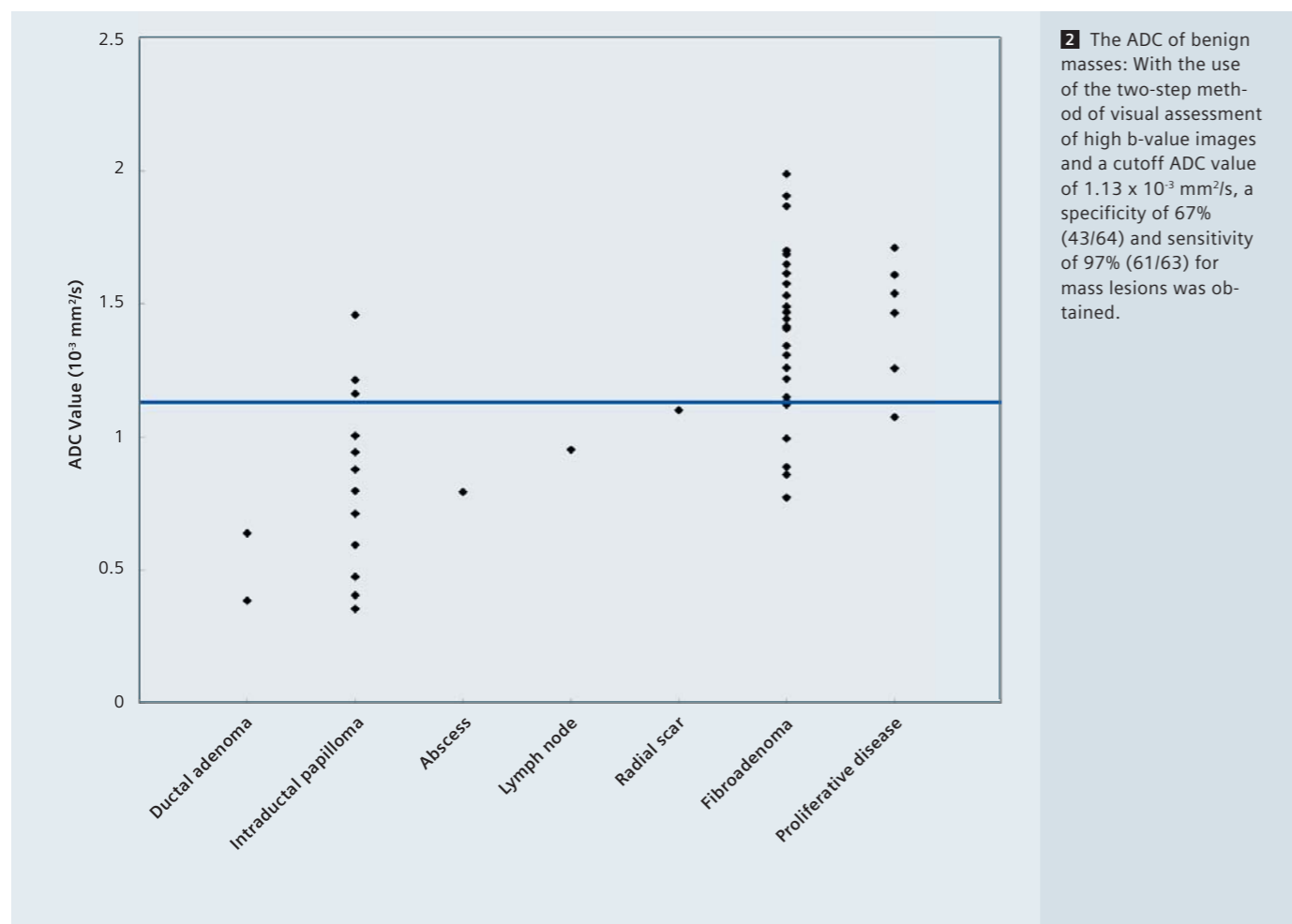
1D Subtracted image shows 2 irregular masses (BI-RADS-MRI category 4).



1E T2-weighted image shows no tumors.



1F Sagittal multiplanar reconstruction (MPR) images constructed from diffusion-weighted images with b-factors of 500, 1000, 1500, 2000 and 3000 s/mm² show different signal intensity of 2 masses. The ADC of mass in upper portion was 1.88 × 10⁻³ mm²/s, and that in lower portion was 0.76 × 10⁻³ mm²/s. Histology of the lesions were benign proliferative disease (upper portion) and invasive ductal carcinoma (lower portion).



2.5 minutes. Motion-probing gradient pulses were applied along the X, Y, and Z directions with b-values of 500, 1000, 1500, 2000 and 3000 s/mm^2 . SPAIR (Spectrally adiabatic inversion recovery) was used for fat suppression. Dynamic MRI using a 3D fat-suppressed VIBE (volumetric interpolated breath-hold examination) sequence with parallel acquisition [6] included three time-points and a native scan. Both breasts were examined in the coronal plane on the first-, second-, and third-phase dynamic images, acquired at 30 seconds, 1.5 minutes, and 4.5 minutes, respectively. The right and left breasts were examined sagittally using the VIBE sequence without parallel acquisition at 2.5 minutes and 3.5 minutes, that is,

between the second- and third-phase images, respectively.

Results

No previous studies, to the best of our knowledge, have used visual assessment of high b-value images for the detection of breast lesions. With the use of the two-step method of visual assessment of high b-value images and a cutoff ADC value of $1.13 \times 10^{-3} \text{ mm}^2/\text{s}$, we achieved a specificity of 67% (43/64) and sensitivity of 97% (61/63) for mass lesions, regardless of the lesion size (Figs. 1–3). The 21 false-positive mass lesions were histologically characterized as intraductal papilloma (n = 9), ductal adenoma (n = 2), fibroadenoma (n = 6),

benign proliferative disease (n = 1), radial scar (n = 1), lymph node (n = 1), and abscess (n = 1). Using this cutoff value ($1.13 \times 10^{-3} \text{ mm}^2/\text{s}$), only mucinous carcinoma was misclassified. Mucinous carcinoma consists of pure and mixed variants. While mucinous carcinoma with dominant mucus lakes may have such high ADC values, it can still be diagnosed using other methods. Micropapillary carcinoma also had a high ADC value ($1.06 \times 10^{-3} \text{ mm}^2/\text{s}$). This tumor was histologically characterized by a proliferation of tumor cell clusters within empty stromal spaces. We speculate that the water in the empty spaces could move more randomly as compared with that in the interstitium of invasive ductal carcinoma.

In summary, all of the cases of invasive carcinoma and mass-forming DCIS were diagnosed, whereas eight non-mass-type DCIS could not be diagnosed.

Conclusion

We believe that DWI is the only sequence which can visualize breast cancers with a high rate of detectability on non-enhanced MRI. Our results suggest that DWI may be helpful in reducing the number of unnecessary biopsies following categorization into BI-RADS-MRI 4 or 5 lesions. However, this modality still has potential pitfalls in relation to the diagnosis of non-mass-type breast lesions. We believe that non-mass-type lesions should be evaluated by morphological characteristics [5–7].

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