Studies on the Ability to Detect Lesions According to the Changes in the MR Diffusion Weighted Images

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This study evaluated the ability of Diffusion-Weight Image (DWI), which is one of pulse sequences used in MRI based on the T2 weighted images, to detect samples placed within phantoms according to their size. Two identically sized phantoms, which could be inserted into the breast coil bilaterally, were prepared. Five samples with different sizes were placed in the phantoms, and the T2 weighted images and DWI were obtained. The Breast 2 channel coil of SIEMENS MAGNETOM Avanto 1.5 Tesla equipment was used for the experiments. 2D T2 weighted images were obtained using the following parameters: TR/TE = 6700/74 msec, Thickness/gap = 5/1 mm, Inversion Time (TI) = 130 ms, and matrix = 224 × 448. The parameters of DWI were that TR/TE = 8100/90 msec, Thickness/gap = 5/1 mm, matrix = 128 × 128, Inversion Time = 185 ms, and b-value = 0, 100, 300, 600, 1000 s/mm. The ratio of the sample volume on DWI compared to the T2 weighted images, which show excellent ability to detect lesions on MR images, was presented as the mean b-value. The measured b-value of the samples was obtained: 0.5 × 0.5 cm = 0.33/0.34 square × cm (103%), 1 × 1 cm = 1.28/1.25 square × cm (102.4%), 1.5 × 1.5 cm = 2.28/2.67 square x cm (85.39%), 2 × 2 cm = 3.56/4.08 square x cm (87.25%), and 2.5 × 2.5 cm = 7.53/8.77 square × cm (85.86%). In conclusion, the detection ability by the size of a sample was measured to be over 85% compared to T2 weighted image, but the detection ability of DWI was relatively lower than that of T2 weighted image.

Keywords : DWI, T2 weighted image, breast, phantom, b-value

1. Introduction

Breast cancer is currently the second frequent malignant tumor next to stomach cancer. The disease occurs most frequently around the age of 45 years. Recently, with the increasing westernization of the diet, the consumption of fats has increased, the birth rate has decreased resulting in less breast-feeding, and menarche and menopause are being delayed [1-3]. Therefore, the age of breast cancer patients has decreased and the incidence has increased. In addition, according to the data from the Korean cancer center until 2007, there is an increasing trend for female cancers and death rate. In America, Europe and other developed countries, where the incidence of breast cancer is high, the death rate is low, which has been attributed to early treatments on account of the early diagnosis of breast cancer [4, 5]. Mammography is the most basic test for such early detection and diagnosis of breast cancer, and breast sonography and Breast Magnetic Resonance Imaging have been performed as supplementary tests. With the improvement in techniques, breast magnetic resonance imaging has the advantages in that the image contrast is excellent, the anatomical evaluation is feasible, and both breasts could be examined simultaneously. Therefore, its application is on the increase albeit gradually [6-8]. On the other hand, the test time is long and the number of images is large. Moreover, the test cannot be performed in cases allergic to contrast agents. In contrast, breast diffusion weighted imaging has advantages it that can be performed in a short time, the entire breast can be scanned, its evaluation is relatively simple, and contrast agents are not required. Diffusion weighted imaging is a method that depicts the movement of water in the intracellular and extracellular space. In cases with a skeletal muscle injury, it was reported that changes in signal

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intensity could be diagnosed early [9]. In addition, the level of water diffusion presented as numerical values is referred to as the apparent diffusion coefficient (ADC). The ADC was reported to be sensitive to changes in the cellular matrix and provides useful information for diagnosis [10]. Currently, although many studies pertinent to diffusion weighted imaging on the nervous system or the musculoskeletal system have been reported, there are few reports on breast diffusion weighted imaging.

Therefore, this study examined the detection ability per each size of the samples placed in phantoms using Diffusion-Weight Image (DWI), which is one of pulse sequences used in breast magnetic resonance imaging based on the T2 weighted image.

2. Materials and Method

2.1. Phantom production

Phantom materials were acrylic plastic. Regarding the size, the diameter, height and shape was 11 cm, 9 cm and cylindrical, respectively. They were classified into two types depending on the size of the specimens. The specimens used in the phantoms were a slightly hard protein that was square in shape. Five experimental specimens with different sizes, 0.5 × 0.5 cm, 1 × 1 cm, 1.5 × 1.5 cm, 2 × 2 cm and 2.5 × 2.5 cm (width × height cm), were prepared (Fig. 1).

First, depending on the size of the specimen, the phantoms were divided into two phantoms, A and B. In the space of phantom A, protein materials, 0.5 × 0.5 cm, 1 × 1 cm and 1.5 × 1.5 cm in volume, were placed in the center. In the space of phantom B, protein materials, 2 cm × 2 cm and 2.5 cm × 2.5 cm in volume, were placed in the center. The remaining space was filled with liquid vegetable oil and solidified to simulate the breast fat (Fig. 2).

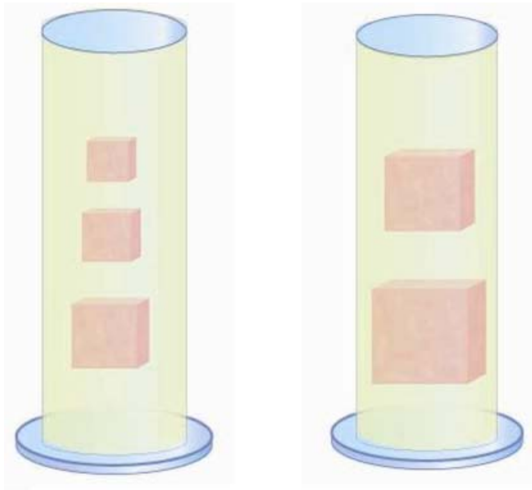

Fig. 2. (Color online) In the space of the phantom A, protein materials 0.5 cm × 0.5 cm, 1 cm × 1 cm, or 1.5 cm × 1.5 cm in volume were placed in the center of phantom, in the space of the phantom B, protein materials 2 cm × 2 cm, or 3 cm × 3 cm in volume were placed in the center of phantom, and the rest space was filled with vegetable oil and solidified.

2.2 Experiment methods

MRI images were obtained with 3.0T MR scanner (Signa 3.0T HDx. GE Healthcare. Milwaukee. WI) and HD T/R 8ch breast array coil (In vivo Corp. Gainesville. FL). The parameters used to acquire the 2D Diffusion Weight Image (DWI) were TR (Repetition Time)/TE (Echo Time) = 8100/90 ms, FOV (Field Of View) = 300 mm, and gradient strength fast mode. The experiments were performed using the following parameters: bandwidth = 1628 Hz/pixel, Inversion Time = 185 ms, NEX (Number of Excitation) = 2, and image matrix = 128 × 128. 2D T2-weighted images were obtained using TR/TE = 6700/74, FOV = 300 mm, gradient strength normal mode, bandwidth = 100/pixel, NEX = 1, and Inversion Time = 130 ms, and Image matrix = 224 × 448.

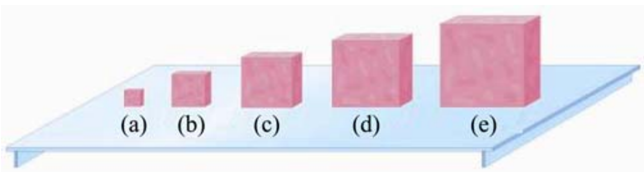

Fig. 1. (Color online) As samples used for Phantoms, 5 squares with different sizes (width x height cm) were prepared. 0.5 cm × 0.5 cm (a), 1 cm × 1 cm (b), 1.5 cm × 1.5 cm (c), 2 cm × 2 cm (d), and 2.5 cm × 2.5 cm (e).

The slice thickness was 5 mm in interval and 1 mm in gap. The center of the phantom was placed in the center area of the breast coil and experiments were performed. To acquire the images, they were divided into T2 weighted images and DWI b-values of 0, 100, 300, 600 and 1000 s/mm, and the specimen volume was measured by the unit (square × cm) using a SIEMENS work station. At that time, the T2 weighted images were obtained by applying a window width of 312, and window level of 123. The DWI images were obtained applying a window width of 436, and a window level of 155, the volume of the specimen was measured more than 5 times, and the average was calculated. In addition, the average of 5 DWI b-values was compared with the mean value obtained from the T2 weighted images.

2.3 Statistical analysis methods

For T2 WI and DWI obtained by each b value (0, 100, 300, 600, 1000 s/mm) according to the size of the specimen, the mean values were compared using an ANOVA test. For more comprehensive analysis, post-hoc analysis was performed using the application of Duncan test. In addition, the mean volume of the DWI obtained by each b value was compared by the application of a paired t-test. In addition, the ratio statistic of the entire average value of the volume of the DWI acquired by each b value based on the volume acquired by T2 WI was obtained. SPSS (version 12.0, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. A P value < 0.05 was considered significant.

3. Results

Figure 3 shows the volume on T2 and DWI (0, 100, 300, 600, 1000) according to the size of the specimen.

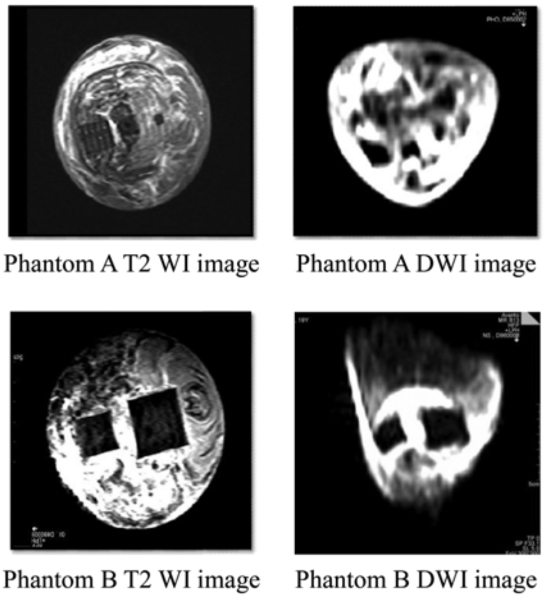

Fig. 3. The volume on T2 WI and DWI obtained by the application of phantoms A and B.

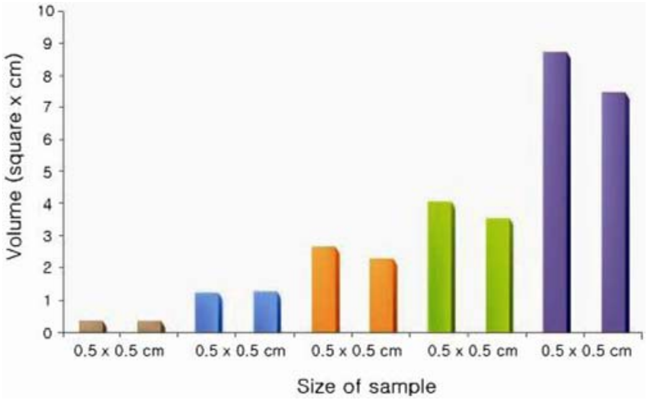

Fig. 4. (Color online) The volume on T2 WI and DWI obtained according to the sample size.

Table 1 and Figure 4 present the measured volumes. On phantom A (sample volume = 0.5 × 0.5 cm, 1 × 1 cm, 1.5 × .5 cm), the p value of the difference of the sample volumes on the T2 weighted images from the sample volume on DWI was 0.245, 0.321 and 0.125, respectively, showing no significant differences ($p > 0.05$). On the other hand, on phantom B (sample volume: 2 × 2 cm, 2.5 × 2.5 cm), the p value was 0.025 and 0.015, respectively. The volume measured on the T2 weighted images was larger than that on the DWI ($p < 0.05$). Table 2 shows the mean of the DWI according to changes in b-value along with the ratio statistics based the T2 weighted images.

When the sample size was 0.5 × 0.5 cm and 1 × 1 cm, the percentage of the volume on the DWI was > 100% (102.4-103.0%), and p value was 0.035 and 0.045, respectively. As a result, the volume on DWI was larger than that on the T2 weighted images ($p < 0.05$). In addition, when the sample volume was 1.5 × 1.5 cm, 2 × 2 cm and 2.5 × 2.5 cm, the percentage of the volume on the DWI was > 85% (85.4-87.3%), and the p value was 0.025, 0.020 and 0.025, respectively. As a result, the volume on the DWI was smaller than that on the T2 weighted images

Table 1. Comparison of the T2 weighted images and DWI according to the change in b-value (0, 100, 300, 600, 1000)

volume		0.5 × 0.5 cm	1 × 1 cm	1.5 × 1.5cm	2 × 2 cm	2.5 × 2.5 cm
T2		0.33 ± 0.01	1.25 ± 0.02	2.67 ± 0.01	4.08 ± 0.04	8.77 ± 0.01
DWI	b - 0	0.33 ± 0.01	1.40 ± 0.07	2.39 ± 0.02	3.44 ± 0.03	7.69 ± 0.22
	b - 100	0.36 ± 0.01	1.23 ± 0.11	2.20 ± 0.04	3.60 ± 0.14	7.53 ± 0.24
	b - 300	0.33 ± 0.11	1.28 ± 0.03	2.34 ± 0.19	3.55 ± 0.22	7.45 ± 0.41
	b - 600	0.33 ± 0.02	1.24 ± 0.08	2.20 ± 0.14	3.63 ± 0.17	7.56 ± 0.32
	b - 1000	0.36 ± 0.04	1.26 ± 0.15	2.28 ± 0.11	3.57 ± 0.18	7.42 ± 0.22
	p	0.245*	0.321*	0.125*	0.025**	0.015**

The interaction effect was determined using a one-way ANOVA model. The post Hoc was performed using the Duncan method. Unit is the square × cm.
*p > 0.05, **p < 0.05

Table 2. The ratio statistics of DWI according to the change in b-value based on the T2 WI

	T_2 (square × cm)	DWI b-value average (square × cm)	percentage (%)	p
0.5 × 0.5 cm	0.33 ± 0.12	0.35 ± 0.14	104	0.035*
1 × 1 cm	1.25 ± 0.21	1.28 ± 0.24	102.4	0.045*
1.5 × 1.5 cm	2.67 ± 0.81	2.28 ± 0.92	85.39	0.025*
2 × 2 cm	4.08 ± 1.32	3.56 ± 1.11	87.25	0.020*
2.5 × 2.5 cm	8.77 ± 2.21	7.53 ± 2.33	85.86	0.025*

The interaction effect was determined using the one-way ANOVA model and Ratio Statistic. *$p < 0.05$

(Table 2) ($p < 0.05$).

4. Discussion

The image contrast of breast MRI is excellent, an evaluation can be performed readily, there are no risks of radiation exposure, and both breasts can be examined simultaneously. Recently, it was reported to be a good test for breast cancer with a higher specificity than any other tests [11, 12]. With such advantages, the continuous development of software, and the improvement of MR hardware has led to an increase in its clinical application. In particular, since diffusion weighted magnetic resonance imaging (DWI) has a magnetic gradient that is sensitive to the diffusion movement of water molecules, the edema caused by cell swelling that develops immediately after ischemic changes as well as the restriction of the diffusion movement of water molecules can be obtained as signal changes [9]. Although studies on diffusion weighted imaging have been conducted primarily in the brain area, recent studies have been conducted on other tissues [13]. Nevertheless, there have been too few studies on breast diffused weighted images. Of these, most studies on breast diffusion weighted images have been conducted as primarily qualitative analysis. In the present study, quantitative studies were performed using phantoms. In other words, previous studies evaluated the diagnostic value of breast diffusion weighted imaging. In the present study, however, breast phantoms were prepared, DWI images were obtained according to the sample size, the volume was measured, and the detection ability was evaluated.

The results showed that the detection ability according to the sample size was > 85% compared to T2 weighted imaging. Nevertheless, the detection ability of DWI was somewhat lower than T2 weighted imaging. One possible reason is that the maximization of weak signals generated by diffusion might result in ghost artifacts, which are generated from the phase direction, as the size becomes larger, as well as susceptibility artifacts, which can be generated between tissues and air. The experiments also showed difficulty in measuring samples < 1 cm^2 because the voxel size is too large on account of the large FOV and low resolution (image matrix = 128 × 128).

Nevertheless, the diffusion coefficient of water molecules that comprises approximately 60-70% of the body is different due to a range of physiological environments. Therefore, such information of the blocking of blood flow in the body, abscess and tumor necrosis is presented as a range of signal intensities. Based on the characteristics, diffusion weighted imaging can non-invasively and qualitatively analyze the characteristics of human tissues that are altered by lesions [14, 15]. Currently, its usefulness in the nervous system, abdomen and urological system is on the rise [16]. In addition, diffusion occurs more readily in liquid substances than solid substances, materials with low viscosity, and at high temperatures. These results show that the above technical aspects should be considered more in the preparation of phantoms used in experiments.

5. Conclusions

In breast MRI test, diffusion weighted imaging provides more information for diagnosis, but is impeded by the distortion of images and artifacts generated by a range of causes. More comprehensive studies will be needed to resolve these problems. In addition, it is believed that the diagnostic efficacy may be maximized more if DWI can be applied in a range of fields including the previous nervous system.

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