TECHNICAL NOTE

Rice Pads Reduce Geometric Distortion of Echo-planar Diffusion-weighted Images of the Cervical Spinal Cord

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We investigated whether a rice pad could be used to reduce the geometric distortion in echo-planar diffusion-weighted images of the cervical spinal cord. In 10 healthy volunteers, we obtained sagittal plane images using the same imaging parameters with and without a rice pad. Two reviewers classified geometric distortion and visually assessed images. Use of a rice pad significantly reduced geometric distortion in the cervical spinal cord.

Keywords: diffusion, echo planar imaging, MRI, rice pad, spinal cord

Introduction

Diffusion-weighted images (DWI) have been reported useful in assessing the spinal cord as well as the brain.1 However, such images obtained using echo-planar imaging (EPI) are susceptible to effects from magnetic field inhomogeneity of the cervical region. Geometric distortion occurs even with optimum shimming and can make diagnosis difficult.

We therefore attempted to discern a simple method that would not rely on special imaging methods or hardware and that could reduce the geometric distortion of DWI using EPI.2–4 One way to lessen the effect of magnetic susceptibility is to place a material with magnetic susceptibility similar to that of the human body at the boundary of the air and human body,5–9 and the usefulness of rice pads for this purpose has recently been reported.7–9 Because their similar magnetic susceptibility to that of the human body can improve susceptibility effect, we hypothesized that rice pads could reduce the geometric distortion in DWI using EPI.

In this study, we investigated whether rice pads could reduce such distortion of the cervical spinal cord in DWI using EPI.

Material and Methods

Subjects

Subjects were 10 healthy volunteers (5 men, 5 women; aged 19 to 55 years, mean age, 42 years) with no current disease of the neck and spine and no history of major trauma. All subjects gave informed consent prior to participation in the study. The study protocol was designed in accordance with the Declaration of Helsinki of 1975, as revised in 1983.

Experimental methods and imaging conditions

All images were acquired using a 1.0-tesla magnetic resonance (MR) imaging system (Magnetom Harmony, Siemens, Erlangen, Germany). We used maximum gradient field strength of 20 mT/m, slew rate of 50 mT/m/s, and a circular polarization (CP) head/neck array coil.

To prepare rice pads 1820 g in weight and 48 cm × 11 cm × 4 cm in size, we placed uncooked, polished rice of the short-grained Japonica variety that had been stored at room temperature into a nylon stocking (Fig. 1a).

We acquired neck images with the rice pad wrapped around the subject’s neck (Fig. 1b, c) and without the rice pad (Fig. 1d) using the same imaging parameters for DWI using EPI. When not used,
the rice pad was removed with care to avoid moving the head position. Parallel imaging was not used. The imaging plane was set in the sagittal section. The parameters for EPI DWI were: repetition time (TR), 8000 ms; echo time (TE), 159 ms; band width (BW), 780 Hz; b-factor: 900 s/mm²; slice thickness, 4.0 mm; slice gap, 0.8 mm; number of slices, 11; matrix, 128×84; rectangular field of view (FOV), 88×88 mm; number of acquisitions, 20; and acquisition time, 5 min 28 s. We used chemical shift selective (CHESS) imaging to suppress fat signals.

To compare the changes in the anatomical configuration of the cervical spinal cord with and without the rice pad, we acquired sagittal T₂-weighted images after DWI using EPI and used parameters: TR, 4000 ms; TE, 108 ms; BW, 195 Hz; echo train length, 23; slice thickness, 3.0 mm; slice gap, 0.6 mm; number of slices, 11; matrix, 256×253; phase over sampling, 100%; FOV, 28 cm; number of acquisitions, 1; and acquisition time, 1 min 32 s.

Image evaluation
One radiologist and one radiologic technologist visually evaluated all images by comparing those obtained by echo-planar DWI with and without the rice pad with the sagittal T₂-weighted images. They graded the echo-planar diffusion-weighted images from one through four: 4 = excellent, anatomical configuration of the spinal cord nearly the same as in the sagittal T₂-weighted images, no apparent geometric distortion; 3 = good, relatively mild anterior curvature of the spinal cord when compared with the sagittal T₂-weighted images, minimal geometric distortion; 2 = average, considerable bending of the spinal cord either anteriorly or posteriorly when compared with the sagittal T₂-weighted images, moderate geometric distortion; and 1 = poor, considerable bending both anteriorly and posteriorly, severe geometric distortion.

The 2 reviewers were blinded to whether an image was acquired with or without the pad, and they visually assessed the images independently.

For statistical analyses, we used weighted kappa value to evaluate interobserver agreement for the scores given by the 2 reviewers. A weighted value less than 0.20 was considered poor; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, good; and 0.81 to 1.00, excellent. The mean of the scores of the 2 reviewers was then determined, and Wilcoxon’s signed rank sum test was used for between-group comparisons. \( P < 0.05 \) was considered statistically significant.

Results
The mean scores for geometric distortion in the
cervical spinal cord for images acquired with the rice pad (3.25) and without (2.00) demonstrated the clear superiority of the images with the rice pad (Table) (Fig. 2).

The kappa coefficient for the evaluation scores of the 2 reviewers (0.489) indicated fair correlation. Wilcoxon's signed rank sum test demonstrated a statistically significant difference between the mean scores with and without the rice pad ($P=0.005$) (Table).

**Discussion**

This study demonstrated significant reduction in geometric distortion using a rice pad in DWI with EPI. Such reduction in geometric distortion has been reported using DWI with image sequences with fewer susceptibility artifacts and sense encoding (SENSE), but we believe ours is the first report of reduced geometric distortion in DWI using EPI and a rice pad.

One reason for the reduced distortion of EPI diffusion-weighted images with the rice pad may be that the magnetic susceptibility of rice ($-8.2 \times 10^{-7}$ emu) is similar to that of human tissue (cytoplasm in the human body, $-7.2 \times 10^{-7}$ emu) and water ($-7.2 \times 10^{-7}$ emu). Another reason is that wrapping a rice pad with such similar susceptibility around the concave neck creates a single uniform structure from the neck to the chest. The human body has various irregularities where the linearity of the gradient magnetic field necessary for MR imaging is not maintained. In particular, the severely irregular shape of the neck makes it difficult to obtain good EPI DWI. In this study, however, we felt that placing the rice pad around the neck considerably reduced the change in magnetic susceptibility between the human tissue and air.

Several studies report that the use of rice pads improved magnetic field inhomogeneity, which supports our finding of reduced geometric distortion on EPI DWI, and the pads did this by improv-

| SCORE | with rice pad | without rice pad |
|-------|--------------|------------------|
| 4     | 7            | 0                |
| 3     | 11           | 3                |
| 2     | 2            | 14               |
| 1     | 0            | 3                |
| Total | 20           | 20               |
| Mean  | 3.25         | 2.00             |

**Table.** Visual evaluation score of geometric distortion in echo-planar imaging (EPI) diffusion-weighted images (DWI) of the neck

Fig. 2. Comparison of images from the same subject. a: Sagittal T2-weighted image without the rice pad. b: Sagittal diffusion-weighted image (DWI; $b=900$ s/mm²) without the rice pad. c: Sagittal T2-weighted image with the rice pad. d: Sagittal DWI ($b=900$ s/mm²) with the rice pad. Moderate anterior distortion is seen on the sagittal echo-planar DWI without the rice pad (b) (arrowheads). Reduction in geometric distortion is clearly seen on the sagittal echo-planar DWI with the rice pad (d) (Grade 3) (arrow) compared with that without the rice pad (b) (Grade 2).
ing the fat suppression effect using CHESS. Thus, findings of the previous reports and the results of our study represent 2 different phenomena-improved inhomogeneity of the fat suppression effect in CHESS and reduced geometric distortion in DWI using EPI. Both of these phenomena may be the result of the same principle; the rice pad decreases the inhomogeneity in magnetic susceptibility between human tissue and the air layer.

Methods to avoid geometric distortion in DWI include the use of imaging sequences other than EPI, which are less affected by magnetic field inhomogeneity. Single-shot fast-spin-echo (SSFSE), PROPELLER, and SENSE are known sequences that can be used in place of EPI to obtain diffusion-weighted images with less distortion. With SSFSE, there is little geometric distortion of images, but disadvantages include lower signal-to-noise ratio (SNR) than that with other sequences and the image blurring that is characteristic of fast-spin-echo sequence. PROPELLER has little geometric distortion and is not readily affected by subject movement, but it can only be used with some machines. Methods using SENSE are reported effective against geometric distortion of images and in general use, but the imaging can only be performed with machines that can use parallel imaging, and there are specific SENSE-specific artifacts, such as ghost artifacts caused by FOV restrictions.

Compared with these methods, the use of rice pads is advantageous because simply placing a pad on or around the area to be imaged can reduce geometric distortion. There is no need to use special imaging methods to improve susceptibility artifacts or parallel imaging for the image distortion that occurs in areas that have strong magnetic field inhomogeneity, such as the neck. Use of rice pads enables acquisition of good diffusion-weighted images using only EPI, even with machines with low gradient field strength or low slew rate, machines without good magnetic field homogeneity, and machines not equipped with parallel imaging to enable SENSE.

Diffusion-weighted imaging using EPI may also be possible in regions where severe magnetic susceptibility artifacts occur, such as the breasts or legs. Moreover, the capacity of the technique to reduce the geometric distortion of the image may contribute to the acquisition of better diffusion tensor images or tractography images.

The material stability of rice is another advantage. The technique requires only rice and a bag, both of which are inexpensive and easy to obtain. The desired size and shape can be formed arbitrarily by filling the bag or sack with rice.

When using a surface coil, use of a rice pad increases the distance between the coil and body, which may decrease SNR, but placement of the coil in close contact with the body will not decrease the SNR to a level where image quality is clearly deteriorated. Moreover, because the magnetic susceptibility of rice is similar to that of the human body, neither will inductive loss (magnetic loss) and dielectric loss.

Our study is limited because it examined only the cervical spinal cord. Research is also needed to investigate regions of the body where severe magnetic susceptibility artifacts occur and acquisition of DWI with EPI is difficult with good imaging quality. Moreover, we did not explore different shapes of the rice pad; even better results might be obtained using an optimal pad shape for the area to be imaged. Finally, this study was conducted at 1.0T, and magnetic field inhomogeneity is known to become even greater in machines with high static magnetic field. Thus, it will be necessary to investigate whether the same effect can be obtained with higher static magnetic fields.

Conclusion

Wrapping a rice pad around the neck is a simple technique for reducing geometric distortion in echo-planar diffusion-weighted images of the cervical spinal cord and does not require the use of special imaging methods.

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