TECHNICAL NOTE

Reduction of a High-field Dielectric Artifact with Homemade Gel

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We developed an original dielectric-equivalent gel (Japanese Patent Application ID: P2004-236876A, February 6, 2003) pad that could improve inhomogeneous images caused primarily by B_1 homogeneity on a high-tesla magnetic resonance (MR) system. Made easily from various ingredients, our gel could reduce interference from radiofrequency waves at an object's surface and show changes in B_1 inhomogeneity. We herein assess the gel's effect using a plastic-bottle phantom on a 3T MR system.

Keywords: B_1 inhomogeneity, central brightening, dielectric artifact, gel pad

Introduction

Acquisition of homogeneous images is difficult using high-tesla magnetic resonance (MR) imaging because of the inhomogeneity of B_1 field distribution.^{1–4} Central brightening, the most noticeable artifact, is also called dielectric artifact and is attributed primarily to dielectric resonance.^{1,3,5} Other causal factors include interference related to shortened radiofrequency (RF) wave on a high-tesla magnetic field, electromagnetic wave impedance mismatching of the air-to-tissue interface at the surface of an object, and multiple current-carrying elements in RF coils.^{1,6–8} Shortened RF wavelengths cause various problems in the high-tesla magnetic field because changes in wavelength are inversely proportional to the strength of B_0 . Shortened wavelength would be partly reflected, partly transmitted, and partly absorbed at an object's surface.⁶ These phenomena also cause inhomogeneous B_1 field distribution.

Several methods to improve B_1 inhomogeneity have been reported and include use of a novel RF transmitter coil system, modified RF pulse sequences, adequate imaging processing after examination, and dielectric material around objects during examination.^{2,3,7,8} We have reported an original method to develop a dielectric-equivalent gel with better impedance matching for human skin.^{6,7} Use

of the gel between an object and the receiver coil during MR scanning can improve B_1 inhomogeneity in a high-tesla magnetic field by reducing the interference and reflection of RF waves at the object's surface. In this study, we assessed the effect of our home-made gel pad using a plastic-bottle phantom on a 3T MR system.

Materials and Methods

Gel pad

We used our home-made gel pad and one commercially available from General Electric Healthcare (Milwaukee, WI, USA) as a reference. We made our pad from gelatin produced from pig skin (13.5%), honey syrup (50.1%), NaCl (1.7%) and distilled water (34.7%), utilizing a method reported previously.⁷ The gelatin corresponds to solidity and relative dielectric constant, honey syrup corresponds to relative dielectric constant with antiseptic action, and NaCl shows conductivity. The gel's dielectric equivalent is adjusted to approximate that of human skin. The gel is contained inside a plastic bag and is used as a flat and square pad for scans (Fig. 1). Each pad was 2 cm thick.

Phantom

We utilized a columnar plastic-bottle phantom made from polyethylene and measuring 17.5 cm in diameter by 34 cm long with wall thickness less than 1 mm. We filled the phantom with tap water from Chiba City; we did not use distilled water because its T_1 relaxation time is longer than that of

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Fig. 1. **a)** Our home-made gel pad made from various ingredients by our original method. The gel is inside a plastic bag. **b)** Commercially available pad from General Electric Healthcare (Milwaukee, WI, USA).

tap water.

MR examination

We conducted MR examination on a 3T system (Signa Exite 3.0T, GE Healthcare, Milwaukee, WI, USA) with a standard head coil (16 elements, birdcage-type coil, diameter = 28.8 cm, length = 36.4 cm). We acquired spin echo (SE) T_1 -weighted images (repetition time [TR]/echo time [TE] = 600/10 ms; matrix size = 256×256 ; field of view [FOV] = 24×24 cm; slice thickness = 5.0 mm; spacing = 0 mm; number of acquisitions = 1) and fast spin echo (FSE) T_2 -weighted images (TR/TE = 4000/150 ms; echo train length (ETL) = 16; matrix size = 256×256 ; FOV = 24×24 cm; slice thickness = 5.0 mm; spacing = 0 mm; number of acquisitions = 1). Transmitter gains (TGs) were automatically defined, but checked before each scan began. During SE T_1 -weighted imaging, TGs were 61 without pad, 69 with our home-made gel pad, and 88 with the commercially available pad; during FSE T_2 -weighted imaging, the corresponding TGs were 76, 84, and 105. The difference in transmitter gain was 0.1 dB. Receiver gains were analog = 14 and digital = 15 for all scans, which were fixed during the whole scan although they were also automatically defined. The difference of receiver gain was 3.0 dB. After each scan, we drew a horizontal line on the image of the phantom and made profile curves of the signal intensity on the console with GE Signa EXCITE HD 3.0T Version 12. We compared changes in the shape of profile curves before and after using the 2 pads. We also compared changes in the averaged value (mean $\pm$ standard deviation [SD]) of signal intensities.

Results

Spin echo T_1 -weighted image

Signal intensity in the paracentral region of the phantom without pad was higher than that in the

peripheral and center (Fig. 2a), and the profile curve was M-shaped (Fig. 2b). After putting each pad on the phantom, the highest signal intensity moved to the center (Fig. 2c and 2e), and the profile curve of the signal intensity changed from M-shaped to convex (Fig. 2d and 2f). These changes were seen for both the home-made and commercially available gel pads, and the effects of the home-made and commercially available pads were similar. The mean $\pm$ SD of signal intensity inside the phantom was 775.6 ± 324.0 without pad, 444.0 ± 222.7 with our home-made gel pad, and 470.0 ± 230.0 with the commercially available pad. The mean value and SDs of signal intensity decreased though TGs increased in both scans of the 2 pads.

Fast spin echo T_2 -weighted image

FSE T_2 images and SE T_1 -weighted images showed similar signal intensity distribution. Signal intensity in the paracentral region of the phantom without pads was higher than that in the peripheral and center (Fig. 3a), and the profile curve was M-shaped (Fig. 3b), but the concave at the center of the graph of signal intensity was smaller than on SE T_1 -weighted images. After placing each pad on the phantom, the highest signal intensity moved to the center (Fig. 3c and 3e), and the graph of signal intensity changed to a convex curve from an M-shaped curve (Fig. 3d and 3f); these changes were seen with both our home-made gel pad and the commercially available pad on SE T_1 -weighted images. The effects of our home-made gel pad and the commercially available pad were similar. The mean $\pm$ SD of signal intensity inside the phantom was 3981.7 ± 1477.5 without pad, 3069.9 ± 1443.4 with our home-made gel pad, and 2469.3 ± 1108.3 with the commercially available pad. The mean value and SDs of signal intensity decreased though TGs increased on both scans of the 2 pads, and these results were the same as on SE T_1 -weighted images.

Fig. 2. **a)** Spin echo (SE) T₁-weighted image of a plastic-bottle phantom filled with tap water from Chiba City, Japan. Signal intensity inside the phantom shows a ring-like figure. **b)** and **c)** SE T₁-weighted images of the plastic-bottle phantom wrapped with the pad. The pattern of signal intensity inside the phantom changed. High signal intensity moved to the center. **d)** Linear graph of signal intensity transverse inside the plastic-bottle phantom. The graph is M-shaped. **e)** and **f)** Linear graph of the signal intensity transverse inside the plastic-bottle phantom. Convex graph. Images of **b)** and **e)** with our home-made gel pad and **c)** and **f)** with the commercially available pad.

Discussion

Inhomogeneous images, which are mainly caused by B₁ inhomogeneity, represent an important problem when utilizing a high-tesla magnetic resonance

(MR) system. Several methods have been reported to solve this problem, but our home-made gel pad is the easiest and simplest.^{2,3,7,8}

We assume the main effect of our home-made pad is the reduction of interference from radiofre-

Fig. 3. **a)** Fast spin echo (FSE) T₂-weighted image of the plastic-bottle phantom filled with tap water from Chiba City, Japan. The signal intensity inside the phantom shows a ring-like figure. **b)** and **c)** FSE T₂-weighted images of the plastic-bottle phantom wrapped with the pad. The pattern of signal intensity inside the phantom changed. High signal intensity moved to the center. **d)** Linear graph of signal intensity transverse inside the plastic-bottle phantom. The graph is M-shaped. **e)** and **f)** Linear graph of the signal intensity transverse inside the plastic-bottle phantom. Convex graph. Images of **b)** and **e)** with our home-made gel pad and **c)** and **f)** with the commercially available pad.

quency (RF) waves at the surface of objects, where a shortened wave would be partly reflected, partly transmitted, and partly absorbed and is related to the difference in the dielectric property of materials, such as air and the human body, during human

scans.⁶ Suitable impedance-matched materials enable the gel to reduce the dielectric mismatch between air and the human body.⁶ RF field shimming with suitable dielectric material between the sample and the RF coil has been reported to be more effective.

tive and versatile than without.⁸ The high signal-to-noise ratio (SNR) region could be moved from one area to another by placement of the pad, thus allowing manipulation of the RF field to achieve not only a more homogeneous RF field distribution, but also a focused area of high SNR. The pad will help enhance a certain area for investigation, such as for functional MR imaging and spectroscopy. Our results were similar to those of Yang's group⁸ regarding the movement of the region of high signal intensity,⁸ and our home-made gel pad can be used for the same purposes as theirs.

With regard to the contents of pads, Yang and colleagues used double-distilled water as the dielectric pad for their simulation and experimental study.⁸ They speculated that because water produces a strong signal that saturates the receiver and decreases the dynamic range of the digitizer, it is not a suitable high-dielectric material for the same purpose as ours, and its movements and geometry were difficult to control. They suggested that solid-state materials with a high dielectric constant and low conductivity would be more appropriate. We could not directly compare their results with ours, but our home-made pad has the potential to match that property because the pad's contents can be easily changed. The solidity, dielectric constant, and conductivity are easily prepared according to demand.

Other advantages of our home-made gel pad are its composition from common ingredients⁶ and its safety for patients even if the pad tears during the scan. In addition, because we can make pads in a variety of shapes and sizes, we can select an appropriate pad for all RF coils.

Our study has some limitations. First, our gel was made to match the electrical characteristics of the human skin for 200 to 400 MHz (4.75 to 9.4T). The electrical characteristics of the radiofrequency (RF) wave did not match at 3T. We need to assess the effect of our home-made gel pad on an MR system with a magnetic field greater than 4.75T. Second, the phantom in this study was not made to match the electrical characteristics of human skin. The results of this study could not be used directly to explain the advantage of our home-made gel pad for a human scan on a high-tesla MR system. We need to assess the effect of our home-made gel pad using a phantom that matches the electrical characteristics of the human body. Third, we did not assess the influence of using different transmitter gains, which are power levels of the RF wave during each scan. TGs were automatically defined before each scan, but we did not use the same TG to

take images with and without pads. TG increased after using pads on both SE T₁- and FSE T₂-weighted images; it was speculated that more RF wave power was needed to obtain the same SNR as before using pads. We focused on changes in the signal intensity of the object before and after using pads. We did not assess the relevance between using a pad and the increase of TG. This relevance may be related to the increase of the specific absorption rate and requires further investigation.

Conclusion

Our home-made gel pad did not completely resolve B₁ inhomogeneity, but was comparable to a commercially available pad and a pad from a previous report in changing the pattern of signal intensity inside an object. There is potential to improve the effect of our home-made pad; further study is needed to find a better method to reduce dielectric artifacts.

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