Flour Pads: Devices to Improve CHESS Fat Suppression

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(Received April 8, 2013; Accepted September 19, 2013; published online January 31, 2014)

Purpose: We compared the suppression of lingering fat signals in chemical shift selective (CHESS) images by pads filled with flour and pads filled with rice in a phantom and human subjects.

Materials and Methods: First, we prepared a phantom by creating an empty space in a mass of lard and filling the space with air, rice, or flour. Then, we obtained MR images of the phantoms in the center of the magnetic field and at a position 8 cm to the left (off-center) to compare lingering fat signals. MR images of the knee were obtained in 10 healthy volunteers using CHESS after placing a polyurethane sponge pillow, rice pad, or flour pad in the popliteal space under the flexed knee. We visually assessed the number of areas with lingering fat signals and the statistical differences among the groups were assessed using Tukey’s test.

Results: Similarly to rice, flour clearly decreased lingering fat signals in the phantom study. A similar effect was obtained in the off-center images. In the volunteer study, the mean number of areas with lingering fat signals was 2.5 with a sponge pillow, 0.5 with the rice pad, and 0.3 with the flour pad. Those numbers were significantly different using flour pad and rice pads compared with sponge pillow (P < 0.001). No significant differences were seen between flour pads and rice pads (P = 0.662).

Conclusion: Flour pads can suppress lingering fat signals in CHESS images.

Keywords: auxiliary pad, CHESS, fat suppression, MRI, nonuniformity

Introduction

Fat-suppressed images are very useful in magnetic resonance (MR) imaging and are obtained using various methods,1-3 and the chemical shift selective (CHESS) method is widely used to suppress fat among them.4 However, sudden changes in magnetic susceptibility between the human body and air can result in CHESS images with poor fat suppression.5 In such cases, for example, in contrast T1-weighted images using CHESS, diagnosis can be difficult because depiction of both normal adipose tissue and damaged inflammation sites as areas of high signal makes unclear the areas of contrast enhancement.6

One inexpensive and simple solution is to place a rice-filled pad next to the region of the body to be imaged. Investigations performed with this method in the neck, shoulder, elbow, wrist, and knee have yielded good fat suppression.7-10

Rice is widely consumed in such places as Japan, China, India, and other Asian countries,11 but we questioned whether an alternative material similarly easy to obtain in other countries might be used for such pads to improve CHESS images. We hypothesized that flour from wheat would be a candidate because its raw material, wheat, is consumed around the world,12 and flour is a processed food product, more easily purchased than unthreshed wheat, and inexpensive.

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The aim of this study was to investigate whether flour pads could improve CHESS fat-suppressed images.

Materials and Methods

A 1.0-tesla MR imaging system (Magnetom Harmony, Siemens, Erlangen, Germany) was used for all studies. The coil was a circular polarized (CP) extremity coil, which was a sending and receiving coil.

Phantom study

Phantom preparation

We prepared a phantom (Fig. 1a) by filling a polypropylene food preservation container (15 × 10 × 4.5 cm) with heated liquefied lard to a height of 2 cm, and a smaller empty container (6 × 4 × 2.5 cm) was placed in its center to create a cavity. We prepared a phantom by filling a polypropylene food preservation container (15 × 10 × 4.5 cm) with heated liquefied lard to a height of 2 cm, and a smaller empty container (6 × 4 × 2.5 cm) was placed in its center to create a cavity. (b) Phantom and container with 500 mL of manganese chloride solution (646 µmol/L) were set into the circular polarized (CP) extremity coil. (c), (d) Measurement position of the phantom inside the magnet. In (c), the phantom is placed in the center of the magnetic field. In (d), the phantom is placed 8 cm to the left.

Fig. 1. The shape of the phantom and its placement in the magnetic resonance (MR) imaging machine. (a) Phantom. Lard was placed in a polypropylene container (15 × 10 × 4.5 cm) to a height of 2 cm, and a smaller empty container (6 × 4 × 2.5 cm) was placed in its center to create a cavity. (b) Phantom and container with 500 mL of manganese chloride solution (646 µmol/L) were set into the circular polarized (CP) extremity coil. (c), (d) Measurement position of the phantom inside the magnet. In (c), the phantom is placed in the center of the magnetic field. In (d), the phantom is placed 8 cm to the left.

Experimental methods

We set the prepared phantom and a container with 500 mL of manganese chloride solution (646 µmol/L) into the CP extremity coil (Fig. 1b) and obtained fat-suppressed images using CHESS under 3 conditions of the small container in the phantom—empty, containing rice (65 g), and containing flour (80 g) (Fig. 2). The volumes of rice and flour were the same. Imaging parameters were: repetition time (TR), 3000 ms; echo time (TE), 48 ms; bandwidth (BW), 96 Hz; echo train length, 7; slice thickness, 4.0 mm; slice gap, 0.8 mm; number of slices, 10; matrix, 256 × 203; field of view (FOV), 18 cm; and acquisition time, one min 31 s.

Fig. 2. Chemical shift selective (CHESS) images were obtained with the small container in the phantom in 3 conditions—(a) empty; (b) filled with 65 g of rice; and (c) filled with 80 g of flour. Images were obtained in 2 locations, at the center of the magnetic field (d–f) and 8 cm from the center of the magnetic field (off center) (g–i). The volume was the same in (b) and (c). Images are (d) air—center, (e) rice—center, (f) flour—center, (g) air—off-center, (h) rice—off center, (i) flour—off center. Lingering fat signals were clearly decreased with both a rice pad (e, arrow) and a flour pad (f, arrow head). For off-center images, an effect similar to that in images in the center of the magnetic field was obtained (long arrowhead).
To examine the effects on fat suppression of the magnetostatic state depending on the position of measurement, we performed phantom measurements in 2 locations, at the center of the magnetostatic field and 8 cm to the left of the center of the magnetic field (Fig. 1c, d). Eight centimeters was the maximum distance setting for the lateral shift of the coil used.

**Image evaluation**

In images obtained with the phantom set in the center of the magnetostatic field, we visually compared fat suppression using air, flour, or rice in the small container. We compared whether lingering fat signals decreased using flour compared with air and with rice. We also compared the images obtained in the center of the magnetostatic field and those positioned away from the magnetic field center (off center) to investigate whether measurement position in the magnetostatic field affected fat suppression.

**Volunteer study**

**Subjects**

Subjects were 10 healthy volunteers (5 men, 5 women; mean age 35 years, range, 20 to 52 years) with no knee joint pain or other health problems and no history of major knee injury or playing of physically strenuous sports. Informed consent was obtained from all volunteers prior to study participation. The ethics committee of Ishikawa Clinic approved the experimental protocol, which was designed in accordance with the Declaration of Helsinki of 1975 as revised in 1983.

**Imaging conditions and experimental methods**

The sponge pillow was made of polyurethane and measured $17 \times 18 \times 7 \text{ cm}$ (Fig. 3a). The rice pad was made by filling a polyethylene bag with uncooked, polished rice of the short-grained Japonica variety. The rice-filled bag weighed 1,000 g and measured $15 \times 18 \times 5 \text{ cm}$ (Fig. 3b). The flour pad was made by filling a polyethylene bag with commercially available unprocessed wheat flour. The flour-filled bag weighed 1,000 g and measured $18 \times 18 \times 5 \text{ cm}$ (Fig. 3c). Both pads were set to the same weight. To ensure a consistent knee flexion angle with all 3 pads, the rice and flour pads were set to the same height (5 cm). The more yielding sponge pillow was set slightly higher to 7 cm.

The transverse section imaged in all subjects was taken with reference to the midsagittal plane. With all the pads, the knee was flexed to the same angle during positioning. Imaging parameters were: TR, 4092 ms; TE, 48 ms; BW, 96 Hz; echo train length, 7; slice thickness, 4.0 mm; slice gap, 0.8 mm; number of slices, 19; matrix, $256 \times 203$; FOV, 15 cm; and acquisition time, 4 min 2 s. The CHESS sequence was used to suppress fat signals.

Using these sequence parameters, images were obtained with each of the objects placed in the popliteal space under the flexed knee—the sponge pillow (Fig. 3d), rice pad (Fig. 3e), and flour pad (Fig. 3f).

**Image evaluation**

One radiologist and one radiologic technologist who were blinded to information regarding the images independently evaluated them visually. To evaluate the effect of fat suppression, they counted the number of areas with lingering fat signals. For all images obtained in this study, high signal intensity judged to be obvious lingering fat signals were apparent in 4 areas—the superior patella, the popliteal space, an area in the upper right corner of the image on the dorsal femur, and an area in the lower left corner of the image on the dorsal lower leg (Fig. 4). The reviewers counted areas with lingering signals on each image and obtained a mean value; lower number of areas indicated good images. When their assessments differed, the reviewers reassessed the image in question together, explained the reasons for their judgments, and resolved their differences by consensus.

Multiple evaluations with Tukey’s test were performed to assess statistically significant differences
among the 3 groups. *P* values of 0.05 were considered statistically significant. We used R for Windows 2.15.0 (http://www.r-project.org/index.html) for statistical analyses.

**Results**

**Phantom study**

When flour was used, there was a clear decrease in lingering fat signals in the phantom (Fig. 2) that was comparable with the decrease observed when rice was used (Fig. 2). Investigation of measurement position within the magnetostatic field revealed a similar fat suppression effect in images obtained off center and in the center of the magnetic field (Fig. 2).

**Volunteer study**

Mean values for the number of the areas with lingering fat signals were 2.5 with the sponge pillow, 0.5 with the rice pad, and 0.3 with the flour pad (Table). For images obtained with the sponge pillow, the mean for all subjects was high; fat suppression was poor in nearly all cases, with conspicuous fat signals in some areas. Images obtained with the rice pad or the flour pad showed good fat suppression in all subjects, and the number of areas with lingering fat signals was significantly lower than with the sponge pillow (*P* < 0.001 for both the rice and flour pads compared to the sponge pillow. Table, Fig. 5). No statistically significant differences were observed between the rice and flour pads (*P* = 0.662) (Table, Fig. 5).
Discussion

This study showed that flour pads in the popliteal space can improve fat-suppressed images using CHESS and perform similarly to rice pads. Reported methods to improve CHESS imaging in MR imaging have included the use of pads filled with perfluorocarbon liquid,13 physiological saline,14 and rice,7–10 but the use of flour has not been reported.

When we used flour, lingering fat signals in CHESS decreased in number in the phantom experiment and disappeared in the popliteal space in human subjects. From this similar effect, we concluded that flour pads may also be applied in practical settings with human patients.

Flour pads suppress lingering fat signals in CHESS because their magnetic susceptibility is similar to that of the human body. The reported magnetic susceptibility of flour, $-8.1 \times 10^{-7}$ emu,15 is similar to that of water ($-7.2 \times 10^{-7}$ emu),16 the primary constituent of the human body, and that of cells ($-7.2 \times 10^{-7}$ emu).17 The magnetic susceptibility of rice is $-8.2 \times 10^{-7}$ emu.15 In our phantom experiment, we observed lingering fat signals when nothing was placed in the empty space (Fig. 2d, g) because there was an abrupt change in magnetic susceptibility between the lard and air. When rice or flour was placed in the space, we observed almost no lingering fat signals (Fig. 2e, f, h, i) because the magnetic susceptibilities of rice, flour, and lard are similar; thus, the abrupt change in magnetic susceptibility between lard and air was suppressed. In the human subjects, placement of a flour pad in the popliteal space suppressed lingering fat signals. This is also thought to be due to suppression of the abrupt change in magnetic susceptibility between the human body and air because of the similar magnetic susceptibilities of the flour pad and human body.

We observed similar fat suppression in off-center images and thus concluded that use of the flour pad did not affect the image even in differing magnetostatic states. It is thought that good fat suppression can be obtained with the flour pad in imaging fields outside the center of the magnetic field, such as with the knee.

Rice is widely consumed and easily obtained in Japan, China, India, and other Asian countries.11 The worldwide distribution of and ready access to flour would increase the availability of fat-suppression imaging using such pads to many more countries. Therefore, depending on the country or region and the availability of the material, either flour or rice could be used for the imaging pads. Other grains might also be used; rice and flour include high levels of starch, so similar effects may be possible using corn starch, tubers, and beans.

Using rice or flour pads to improve CHESS images has many advantages over other methods. Short TI inversion recovery (STIR) is used in cases when good images cannot be obtained by CHESS.2 However, with STIR, the signal-to-noise ratio is low, imaging time is fairly long, and signals are suppressed in both adipose tissue and in tissue with a relaxation time similar to that of fat, and STIR cannot be used with contrast enhancement.4,18 Methods using flour and rice pads do not have these problems. The 3-point DIXON method is thought to provide reliable, uniform fat suppression, but not all machines have the necessary equipment for this technique.3 In contrast, flour or rice can be used with any MR imaging machine.

This study had several limitations. First, it was conducted at 1.0T, so detailed investigations with higher magnetic field strengths will be necessary. Second, only the popliteal space was imaged, so investigations of other sites in which poor fat suppression is observed with CHESS will be necessary. Last, because flour is a foodstuff, care must be taken when making and storing the pads. Because it is a powder, it can be dispersed in the air and tends to stick to hands and clothes; thus, its handling is more difficult than that of rice grains. Flour also easily absorbs water, and its properties can readily change. Therefore, the bags need to be made of a material that prevents the flour from leaking or coming into contact with air or moisture.

Conclusion

Flour pads can improve fat-suppressed images using CHESS. The ability to use flour in addition to rice for imaging pads will make it possible to choose a readily available material in countries around the world to improve fat suppression in CHESS.

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