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Low-Cost Device for Avoiding Bulk Susceptibility Artifacts in Chemical-Selective Fat Saturation MR of the Head and Neck

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Summary: An inexpensive, commercially available travel pillow filled with a suspension of attapulgite provided good suppression of inhomogeneous chemical-selective fat saturation in imaging of the head and neck. This device is assembled from readily available materials at a low cost and compares favorably with a commercially available perfluorochemical-filled device.

Index terms: Magnetic resonance, artifacts; Magnetic resonance, fat suppression; Magnetic resonance, technique

Nonuniform distribution of soft tissue within a coil and the presence of soft tissue/air interfaces both affect magnetic field homogeneity and can cause regional failure of chemical-selective fat saturation and, occasionally, unwanted suppression of water signal, including that from gadolinium enhancement (1–3). Water-filled bags placed over the neck have been used successfully to overcome this problem, but they can be uncomfortable and are hyperintense on T2-weighted images, which can be distracting and degrade image quality. We devised a low-cost device that is easily assembled from common over-the-counter products; it is comfortable, provides good homogeneous fat suppression, and is hypointense on all sequences.

Materials and Methods

We constructed a phantom that contained eight types of animal and vegetable oils that would be rendered hypointense by the fat-saturation process, and suspensions of barium, iron, and clay that are hypointense because of susceptibility effects (4–7). T1- and fast and conventional T2-weighted spin-echo images were obtained with and without chemical shift selective fat suppression. Signal intensities were measured and normalized to water. After the optimum agent (that which was most hypointense on both T1- and T2-weighted images) was determined, we tested it in a range of different bags and holders under clinical conditions. We did not test perfluorochemicals in the phantom study, because they are not readily available and are difficult to handle (8). Instead we decided to compare a commercially available antibulk susceptibility device containing perfluorochemicals (Sat Pad, Alliance Pharmaceuticals, San Diego, Calif) to our own device in the clinical setting.

In our patient studies, we compared the homogeneity of fat suppression, patient comfort, and motion artifacts using traditional water (intravenous) bags on the anterolateral aspect of the neck, the Sat Pad, and a commercially available U-shaped travel pillow partially filled with attapulgite (Advanced Formula Kaopectate) placed behind the neck (Fig 1).

Results

Clay suspensions (attapulgite and kaolin/pectin) were the most hypointense substances tested in the phantom; attapulgite (Advanced Formula Kaopectate) was more hypointense than kaolin/pectin (Kaopectate) on T1-weighted images. Barium suspension was also hypointense to water on all sequences but less so than clay. Signal intensity varied little over the range of concentrations used. Iron suspension was hypointense on T2 but hyperintense on both T1 sequences. Relative signal intensities of the oils varied. In general, they exhibited low intensity on T2- and fat-suppressed T1-weighted images but had very high signal intensity on non–fat-suppressed T1 sequences, which would require that they be positioned after the T1 sequence was performed.

Compared with anteriorly placed intravenous bags filled with water, the posteriorly positioned travel pillow filled with attapulgite provided more homogeneous fat suppression with improved comfort and immobilization (Fig 2). We

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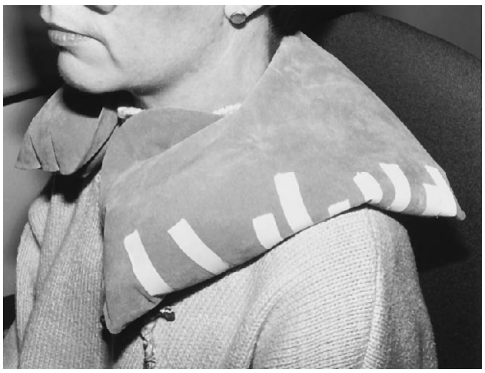

Fig 1. Model demonstrating a commercially available travel pillow for use during airline flights, partially filled with attapulgite. The sides of the pillow have been taped to accommodate the head coil and for further patient comfort. It is positioned around the back of the neck, and when the patient is supine the anterior arms of the travel pillow fold around into the anterior crevice beneath the chin and above the clavicles. Cost of travel pillow is $5; cost of attapulgite is $40.

found it important to remove as much air as possible from the bag to avoid an "empty" air pocket over the anterior neck region. Some travel pillows with short lateral "arms" did not position enough fluid over the anterior aspect of the neck, but regional failure of fat suppression was prevented by placing a second, folded bag containing a small volume of fluid at this site. The Sat Pad also resulted in good fat saturation, was convenient and comfortable to use, and was completely invisible on T1- and T2-weighted images (Fig 3).

Fig 3. T1-weighted (600/11) image of a healthy volunteer with the perfluorochemical (Sat Pad) neck bolster surrounding the neck. Note that it is invisible on a T1-weighted image.

Discussion

Suppression of fat signal has proved useful in imaging structures of the head and neck, particularly in combination with gadolinium administration (1). Successful chemical shift–selective fat-saturation MR imaging depends on the presence of a uniform magnetic field to allow tuning to and saturation of fat, which resonates at 220 Hz downfield from water (2). The uniformity of the magnetic field may be affected by several factors. Abrupt changes in magnetic

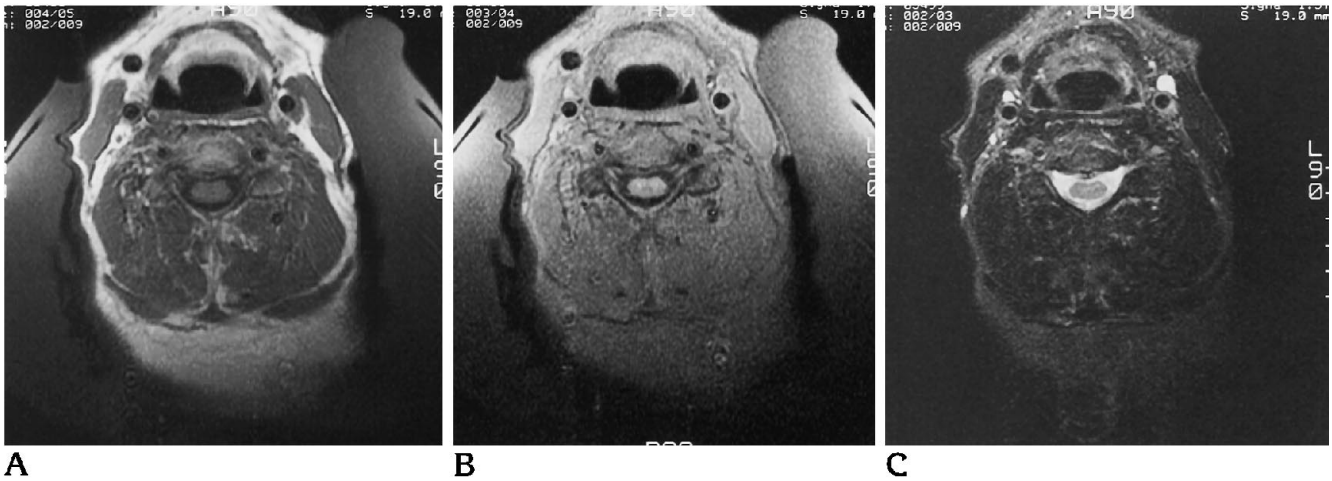

Fig 2. Healthy volunteer scanned with travel pillow filled with attapulgite.

A, Axial T1-weighted (600/11/1 [repetition time/echo time/excitations]) MR scan with a posterior-positioned travel pillow filled with attapulgite. On the T1-weighted image, the contents of the travel pillow can be seen wrapping around the posterior aspect of the neck.

B, Axial T1-weighted (600/11) MR study with fat saturation (same level as A). Note the homogeneous fat suppression throughout the image.

C, Axial T2-weighted fast spin-echo (3000/102/2) MR image using a posterior positioned travel pillow. Note the travel pillow is invisible on the T2-weighted image. Fat-saturation pulse has been applied, and homogeneous fat suppression is accomplished.

susceptibility, such as that which occurs at air/soft tissue and soft tissue/bone interfaces, distort the local magnetic field, causing changes in the resonant frequency and thus local failure of fat suppression. The interfaces between soft tissue and air that occur in head and neck imaging can compound these problems (3). Variation in the volume of soft tissue within different parts of a coil also alters the local field strength slightly through a process termed *bulk susceptibility*. This usually occurs when imaging the neck. At the transitions from one volume to another, the alteration in field strength shifts the precessional frequency of fat and water from their mean frequency. This shift can result in failure of chemical fat saturation. If the magnitude and direction of the chemical shift is close to the 220 Hz offset of fat, then local saturation of water signal by the fat-suppression radio-frequency pulse may occur. In this situation, signal from gadolinium enhancement on T1-weighted images also may be suppressed (1). Fat suppression is usually not required on T2-weighted spin-echo images but can complement T2-weighted fast spin-echo images that otherwise contain hyperintense fat signal that may obscure disease (9).

A common method of preventing degradation of chemical shift selective fat saturation from bulk susceptibility is the placement of "water bags," or small intravenous bags, over the neck to equalize the volume of "soft tissue" or "loading" throughout the coil and to displace the air/soft tissue interface away from the skin surface. However, water bags are less than satisfactory. Water on T2-weighted images is extremely hyperintense and dominates the image in a distracting way. Window and level settings may be selected for photography that suppress this high signal and suboptimally display disease. Furthermore, the high signal emanating from the water bags can be mismapped as motion or wrap-around artifact that may degrade the image. Additionally, the intravenous water bags are uncomfortable, possibly contributing to increased patient motion. A more satisfactory device would be both comfortable and hypointense on all sequences.

Attapulgite was the optimal over-the-counter agent tested for minimizing bulk-susceptibility artifact on fat saturation sequences. A commercially available travel pillow partially filled with the suspension was more comfortable than water bags, improved patient immobilization, and was inexpensive. It provided excellent homogeneity of fat suppression, was invisible on T2-weighted sequences, and was the most hypointense to water on T1-weighted sequences. The total cost of the unit was $45.

The perfluorochemical-filled Sat Pad also provided excellent homogeneity of fat suppression, was comfortable, and promoted patient immobilization. It has the additional advantages of being completely invisible on all pulse sequences and is commercially available in a cosmetically appealing package. The practical advantages of convenience and the aesthetic advantage of being invisible on all sequences must be weighed against the cost of the unit ($2500).

Conclusion

A commercially available travel pillow filled with attapulgite (Advanced Formula Kaopectate) improves homogeneity of chemical-selective fat saturation in head and neck imaging and is hypointense on all sequences. This device is easy to assemble at a low cost and compares favorably with a commercially available perfluorochemical-filled device (Sat Pad).

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