Improving Field Homogeneity on Fat-Suppressed Cervical Spine Images

R. M. Vavrek[1], C. Guclu[1]

[1]GE Healthcare, Waukesha, Wisconsin, United States

Introduction

Susceptibility is a well known phenomenon whereby the magnetic field homogeneity is degraded by changes in geometric shape or magnetic permeability. These effects can be very localized and difficult to shim out. In particular, the cervical spine, situated as it is between the torso and the head, is in a region of significant geometric variation. Fat suppression techniques using the 3 ppm frequency difference between water and fat can be troublesome when there is more than 1.5ppm peak-to-peak field variation over 10cm in the cervical neck region. The frequency variance of water and fat is such that a significant percentage of the two populations overlap each other in frequency. In this case, it is impossible to suppress all of the fat and none of the water using a selective pulse technique.

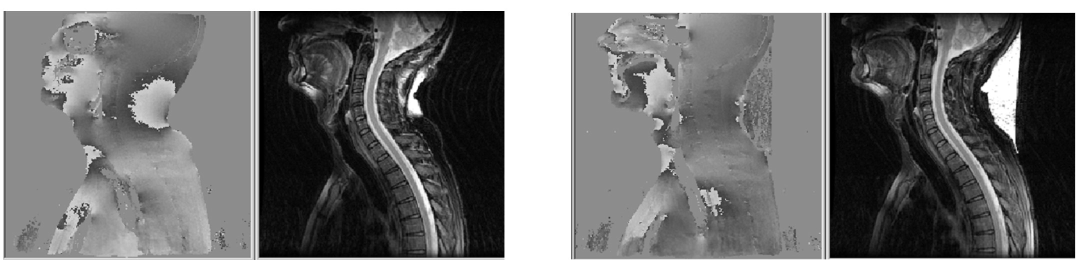
Methods

One known approach is to use a water bag behind and around the neck to reduce the susceptibility. This type of device is usually known as a sat pad. Some issues with using water include doping to reduce the signal, loading of the RF coil, algae growth, and leakage. The ideal fluid would solve all of these issues. Perfluorocarbon[1] fluid is one solution as it does not emit any signal for proton imaging, nor would it load the RF coil. It's drawback is that it's expensive. An alternative to perfluorocarbon that has the same desirable diamagnetic properties is desired. The susceptibility of some materials similar to human tissue susceptibility are [2] shown in Table 1.

TABLE 1

Alumina (Al_2O_3)	-18.1
Silica (SiO_2)	-16.3
Magnesia (MgO)	-11.4
Human Tissue	~(-11.0 to –7.0)

All of the oxides are available in a granular form. Of the three, the silica is probably the easiest to obtain. Generic sand should be avoided, which can contain MRI incompatible substances. Industrial grade silica is usually sufficient. In it's granular state it still retains the desired magnetic properties and in a flexible container can be formed to fit any contour of the human body. SiO_2 doesn't generate an MR signal. The low dielectric constant of SiO_2 minimizes any interaction with the RF field. SiO_2 is also electrically nonconductive, preventing any eddy currents and can safely be used in or around RF components. A clinical scanner can be used to verify magnetic properties. The center frequency of a signal received from a sample in a uniform field is not only dependent upon the sample's intrinsic magnetic properties, but also on the sample geometry and orientation relative to the magnetic field flux. Since silica does not generate a signal, the influence of silica on a proton sample has to be measured. Two plastic cylinders containing water are arranged to create one long cylinder aligned with the main magnetic field. Compared to a sphere, the cylinder with a greater demagnetization factor will show a greater frequency shift. Removing one of the cylinders is akin to a shorter cylinder, reducing the demagnetization factor and shifting the frequency up 34 Hz. Replacing the water cylinder with a silica filled cylinder creates a longer cylinder and greater demagnetization factor. The signal from the one remaining water cylinder is observed to drop to the same frequency as when two water cylinders were used. Placing two cylinders side by side is similar to a short and fatter cylinder, with a more reduced demagnetization factor. Whether both are water or one is water and the other silica, a frequency increase of 68 Hz is observed. The silica appears to have susceptibility similar to water.

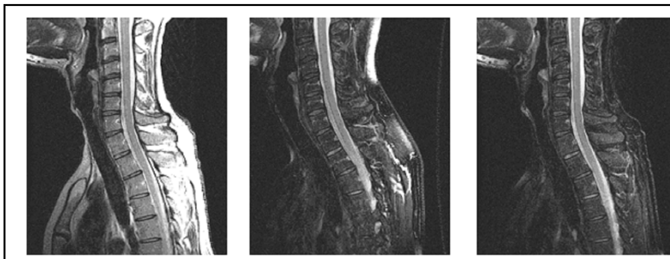


Gray scale range ± 100 Hz   No sat pad, fat not suppressed   Gray scale range ± 100 Hz   Water sat pad (water visible, fat suppressed)

Figure 1: Comparison of susceptibility versus fat-sat uniformity on a volunteer (c-spine). Although water corrects for the field distortion, the proton signal changes the dynamic range of the image.

Results and Conclusions

In volunteer scanning, the silica is placed in a pliable bag behind and around the neck in order to create a more uniform transition from the torso. The results were compared to the images acquired without any pads (Fig 2.) The frequency variation within the neck is observed to decrease, improving the effectiveness of fat saturation. Therefore industrial grade silica is an alternate, low-cost choice in the manufacturing of pads to reduce susceptibility-induced artifacts.



No fat-sat   Fat-sat+no sat-pad   Fat-sat+sat-pad

Figure 2: Effectiveness of using silica-based pads.

References:

1. FC-77 MSDS, 3M Company, St. Paul MN55144, www.3M.com.
2. John F. Schenck, Med. Phys. 23 (6), June 1996 pp 815-850.