Chemical Shift Misregistration Effect in Magnetic Resonance Imaging[1]

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A low intensity artifact appearing at the junction of perirenal fat and renal parenchyma on MR images was recently described. A symmetrical high intensity artifact is also observable on the opposite side of the kidneys as well as at the junction of the right lobe of the liver and adjacent adipose tissue. Both artifacts can be explained as exhibitions of pixel misregistration due to the difference in chemical shifts of fatty and non-fatty organs. Identification of the chemical shift misregistration effect is important since the existence of this artifact may cause erroneous diagnosis of calcification and/or fluid collections.

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A LOW intensity artifact appearing at the junction of perirenal fat and renal parenchyma or renal cyst was described in magnetic resonance imaging (MRI) of the kidneys (1). The origin of the artifact was attributed to the widely different signal intensities of tissues abutting each other. Similar low intensity artifacts have consistently been noticed in our images of the abdomen at the junction of kidney and perinephric fat. Distinctly, these are identified in other areas of fat and non-fatty organ interfaces and clearly seen at the junction of the tip of the right lobe of the liver and adjacent adipose tissue. However, in addition to the low intensity meniscus, a symmetrical, high intensity meniscus has been observed on the opposite kidney- and liver-adipose tissue interface.

Identification and understanding of the origin of these artifacts is important so as to not confuse them with true anatomical changes, such as calcifications, fluid collections, or hematomas.

We offer an explanation of the origin of the low and high intensity artifacts so that the interpreter of MR images knows where to expect such problems and does not read them as abnormalities.

Methods

The imager used for the study, (Siemens, MAGNETOM) operated at 0.35 T. A two dimensional Fourier transform spin-warp technique was used for image reconstruction with voxel dimensions of 2.0 × 2.0 × 10.0 mm in body mode [in principle, equivalent to equipment used by Hricak *et al.* (1), 0.35 T; 2.1 × 2.1 × 7.0 mm voxel size].

In general the localization of signal from a given voxel is based on observation of the proton resonance frequencies as a function of increasing magnetic field strength (field gradient).

However, the signal generating protons in tissues can be classified as belonging to either of the two general categories: water or lipid protons resonating at different frequencies due to different chemical environments. This phenomenon is known as chemical shift. The chemical shift separation of the fat and water protons is about 3.0–3.5 parts per million (ppm), which at 15 MHz Larmor frequency is 45–52 Hz.

For an image reconstructed with a pixel size of 2.0 mm, the gradient strength of 0.92 mT/m expressed in terms of frequency is 78 Hz/pixel.

Results

In general, since the pixel width is greater than the chemical shift separation of the two main signal generating components, the chemical shift effects are invisible. However, for sharp interfaces between predominantly water-containing and fatty organs, special problems may arise.

With the patient in the gantry in a head first, supine position, the phase encoding gradient is along the PA direction while the read-out gradient direction is from (patient's) right to left. The appearance of the chemical shift misregistration (CSM) effect is demonstrated in Figure 1. A distinct low intensity meniscus (dark band) appears on patient's right side of both kidneys, and a symmetrical high intensity structure can be seen on the opposite side of the kidneys (patient's left).

To exclude the possibility of erroneous interpretation of the CSM effect, three other experiments were conducted. The inversion of the read-out gradient (performed by positioning the patient in the gantry in the feet first, supine position) resulted in a symmetrically opposite effect (Fig. 2). Similarly, interchanging the read-out and the phase encoding gradient produced the effect on the anterior and posterior margins of the kidneys (Fig. 3).

To exclude the possibility of motion artifacts, a simple phantom was constructed using a thin wall plastic container of mineral oil immersed in water. As expected, a distinct dark band appeared at the oil-water interface while a high intensity band was visible at the water-oil interface (in the positive read-out gradient direction) (Fig. 4).

Discussion

The CSM effect can be fully explained by considering the pixel intensity as a function of the magnetic field gradient (position) and chemical shift. For tissue containing both fat and water, the pixel intensity represents the sum of signal amplitudes from both components. If no abrupt composition changes are present, the intensity is a function of proton density and T1 and T2 relaxation times.

For a sharp interface between fat and non-fatty tissue, the fat to water interface, and the water to fat interface (as represented by the phantom shown in Fig. 4) should be considered. A particular combination of orientation and position of the interface will show either a signal attenuation or enhancement. The *fat image* appears shifted with respect to the *water image* by the chemical shift difference. The overlap of signals from neighboring pixels produces the CSM effect.

The image appearance in the phase encoding direction is not subject to CSM problems since the pixel-position information is derived from the signal phase rather than from its frequency.

Conclusions

The chemical shift misregistration effect is a potentially serious problem in MR imaging. In the already difficult area of detection of small lesions, calcifications, and fluid collections it will create an additional source of uncertainty. It may also have a beneficial effect in delineating certain interfaces in critical areas such as cardiovascular imaging (heart *vs.* pericardial fat and arterial stenosis). The CSM effect will be more pronounced in high field instruments if gradient magnitudes are not increased linearly with the field strength to decrease the noise and limit the rate of magnetic field change (dB/dt) for multi-section and multi-echo imaging. This smaller relative gradient strength will cause the chemical shift separation to be larger in relation to the pixel frequency range.

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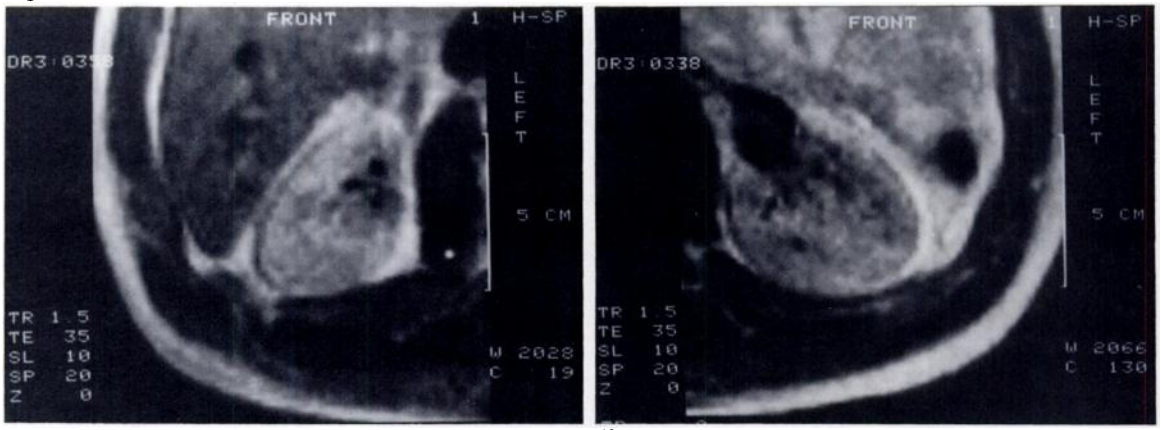
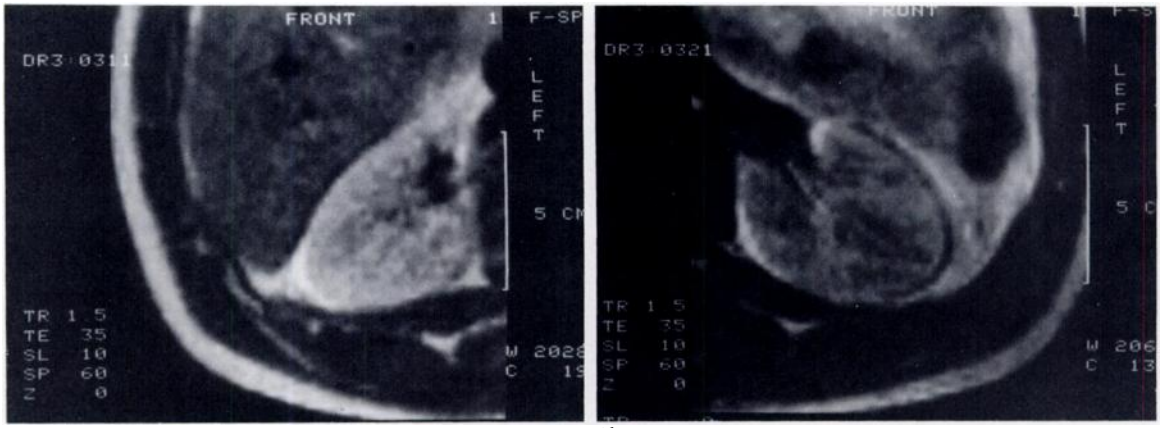
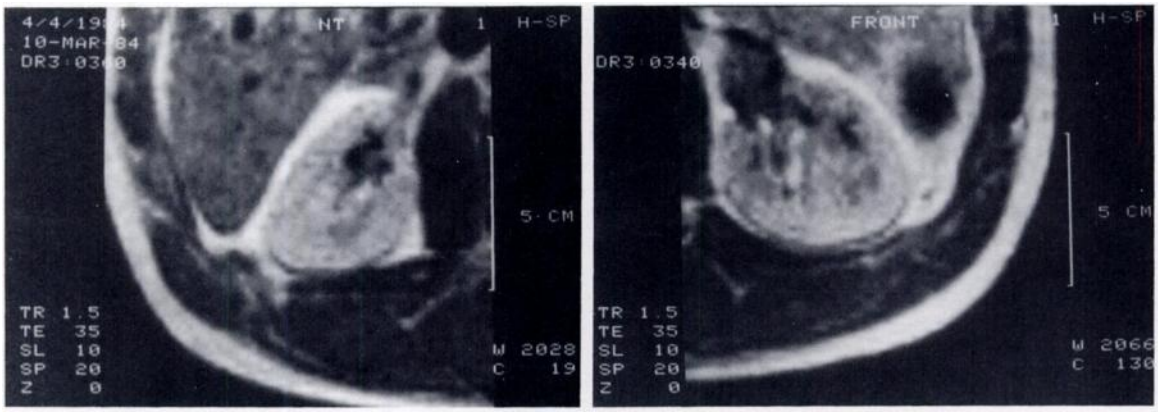
Figures 1-3



1a. 1b.



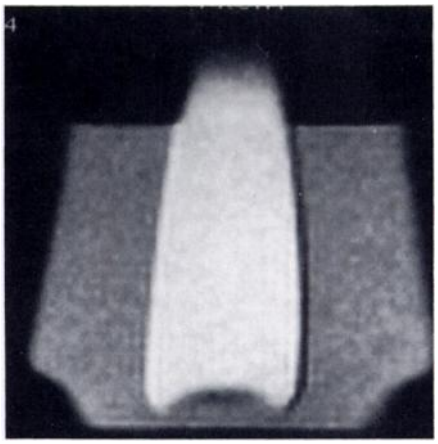
2a. 2b.



3a. 3b.

1a and **b.** Read-out gradient direction from patient's right to left.
2a and **b.** Read-out gradient direction from patient's left to right.
3a and **b.** Read-out gradient direction from patient's posterior to anterior.

Figure 4



Oil (center) and water phantom, gradient orientation as in Figure 1.

References

1. Hricak H, Williams RD, Moon KL, et al. NMR imaging of the kidney: renal masses. Radiology 1983; 147:765-772.