INTRODUCTION

The efficacy of local hyperthermia treatment strongly depends on the knowledge of the temperature distribution within the tumor. Because of the narrow temperature range (37°C - 45°C) an accuracy of better than ±1°C is required. Using the temperature dependence of (i) the T1 relaxation time, (ii) the diffusion coefficient or (iii) the proton resonance frequency (PRF) of water, non-invasive temperature measurements are feasible. In-vivo temperature mapping based on the PRF is difficult because of the low temperature dependence of the resonance frequency (0.01 ppm/°C) and prone to artifacts caused by inter-scan movements of the patient and by susceptibility effects. The use of the praseodymium complex of 2-methoxyethyl substituted DO3A (Pr-ME-DO3A) as a temperature indicator has been proven to be advantageous (1-3) because of the higher chemical shift (~0.13 ppm/°C) of the methoxy group of the complex and its internal reference (water resonance peak). The methoxy group signal is shifted about -24 ppm relative to the water signal (3000 Hz at 3 Tesla). To obtain a spatially resolved temperature map conventional Chemical Shift Imaging (CSI) has the disadvantage of long acquisition times. In this work an Echo Planar Spectroscopic Imaging (EPSI) sequence (4) was implemented capable of a 3D temperature mapping within a breath-hold period.

METHODS

A 50 ml spherical flask (diameter 5 cm) filled with agarose gel (2% agarose) and 10 mmol/l Pr-ME-DO3A was used as phantom. Spectra were recorded on a 3 Tesla whole body scanner (MDSPEC 30/100, Bruker Medizintechnik, Ettlingen, Germany) using a head coil. The CSI was performed applying the EPSI pulse sequence with the following parameters: TR = 200 ms, spatial matrix 20 × 20, voxel size 1 × 1 × 1 cm³, spectral width 900 Hz, data sampled continuously at 50 kHz bandwidth, data-acquisition window 100 ms. Water suppression was achieved by means of three CHEmical Shift Selective (CHESS) sequences. The gradient waveform for the spectral-spatial encoding was trapezoidal with a switching frequency of 900 Hz. Only data acquired at constant gradient were selected for processing. Magnitude spectra of the even and odd echoes were reconstructed separately and summed afterwards. A spectroscopic image of the distribution of the Pr-ME-DO3A complex was created by integration over a spectral range of 60 Hz around the methoxy group signal.

RESULTS

The spectral width of 900 Hz was chosen to separate the methoxy group signal from the water signal by 450 Hz, i.e. half the spectral width. The water signal aliases back into the frequency range of ±450 Hz (Fig. 1). The SNR achieved applying the EPSI sequence is sufficient to determine peak positions of water and methoxy group signals in the spectrum of each voxel. The diameter of the spectroscopic image based on the Pr-ME-DO3A distribution agrees with the inner diameter of the spherical flask (Fig. 2).

CONCLUSION

Compared to a conventional CSI sequence the EPSI sequence applied reduces the time required for imaging by a factor which corresponds to the matrix size (20) in one spatial dimension. Because of the temperature dependence of 0.131 ppm/°C (16 Hz at 3 Tesla) of the resonance shift of the methoxy group of Pr-ME-DO3A and the spectral resolution achieved (Fig. 1) the temperature can be measured to an accuracy of better than ±1°C. Within a breath-hold period the temperature distribution of 6 slices can be determined in this way.

Acknowledgement

This work was supported by the Deutsche Forschungsgemeinschaft (GRK 331 'Effects of temperature on diagnostics and therapy').

References

3. Hentschel, M., et al., Int. J. Hyperthermia (submitted)