3D fast spin echo acquisition for combined amide proton transfer and elecric properties tomography

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Purpose:

Amide proton transfer (APT)[1] and electric properties tomography (EPT)[2] are two novel MR methods for molecular and quantitative imaging of tissue properties. The APT signal is defined by the asymmetry of the magnetization transfer (MT) at +3.5ppm relative to water and reflects the concentration of endogenous cytosolic proteins or peptides as well as local pH. EPT is based on the curvature of the transceive phase (B1 field) of a fast spin echo (FSE) or balanced steady state free precession (bSSFP) image and reflects the electric conductivity of the tissue. Both elevated protein levels and tissue conductivity are related to pathological changes in tumors. Acquisition of the two contrasts in the same imaging sequence could potentially deliver complementary information for tumor tissue characterization. The purpose of this work is to investigate an acquisition protocol, which allows the reconstruction of APT and EPT data from the same imaging sequence. This would reduce the scan time as compared to acquiring APT and EPT in two separate scans as well as provide a better alignment of the two contrasts.

Methods:

In APT, multiple images are acquired with different RF saturation offset frequencies symmetrically distributed around ±3.5ppm to allow for B0 inhomogeneity correction. A sequence with six offset frequencies around $\omega = \pm 3.5$ppm, step size 0.4ppm, and S_0 (ω = -160ppm) was used.

The focus of this work is on FSE sequences, which enable high SNR in APT and suppress off-resonance phase effects that are undesirable in EPT.

Phantom and *in vivo* experiments were performed on 3T MRI scanners (Ingenia and Achieva TX, Philips Healthcare, Best, The Netherlands) using a two channel body coil for transmission and a 13-channel/8-channel head coil for reception, respectively. Complex images are reconstructed to obtain the image phase and allow EPT reconstruction, which is performed for each saturation offset frequency. An optimized RF saturation length of 2s was performed with 100% duty cycle using 40 sinc-gaussian pulse elements, 50ms each[3], using alternated transmission over the TX channels.

An initial *in vivo* study for a combined APT and EPT data acquisition was performed in a tumor patient (anaplastic ependymoma), based on a 2D fast spin echo acquisition with the following parameters: FOV 230×230mm^2, 5mm slice thickness, TE/TR = 6/6019ms. Informed consent was obtained from the tumor patient and the protocol was approved by the institutional review board.

A 3D protocol was investigated in phantom studies. A 3D FSE sequence with driven equilibrium was used with the following parameters: FOV 230×230×95 mm^3, voxel size 1.8×1.8×5 mm^3, centric profile ordering, TE = 6ms, TR = 8000ms.

Phantom experiments were performed using a homogeneous pasteurized egg white phantom (1000ml) as well as a phantom consisting of 6 vials (30ml) filled with a mixture of egg white, water and Magnevist (Bayer Healthcare), with protein concentration of 0.6% up to 7% which were adjusted to equal T1 relaxation (T1=1.1±0.03 s). Measurement of the conductivity in the homogeneous phantom was performed with an independent device (HI8733, Hanna Instruments, Woonsocket, RI, USA) to determine the accuracy of conductivity values obtained from EPT.

Results & Discussion:

Figure 1 shows results of the *in vivo* measurements. The reconstructed APT and EPT images are shown as well as a Gd contrast enhanced and a FLAIR image. In the tumor region (denoted elliptical area in Fig.1), both APT and EPT signals are enhanced. In the ventricles, only the EPT signal is enhanced, and the APT signal is slightly reduced, emphasizing that APT and EPT yield independent information. Figure 2 shows the conductivity obtained from each of the 3D FSE images with different RF saturation offsets for a homogeneous egg white phantom. The RF saturation does not influence the image phase and therefore the conductivity reconstruction is independent of the saturation frequency. This suggests that the SNR of the EPT map can be improved by averaging of the phase images of different ω before EPT reconstruction. Additionally, this may provide a mechanism for correction of asymmetric phase caused by tissue eddy currents in FSE by reversing the gradient polarization for different saturation frequencies. Figure 3 shows the phantom with different protein concentrations as well as the average APT (MTR asymmetry) and EPT (conductivity) signals for each vial. In the egg white-water solution used in the phantom, the protein concentration is correlated with the conductivity, which was confirmed in the phantom experiments (Fig.3 b).

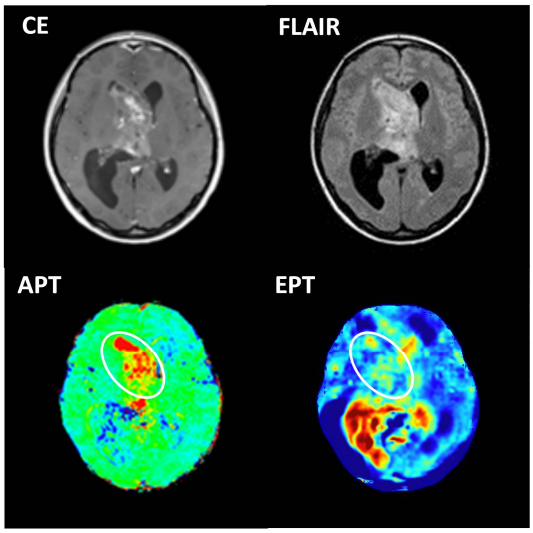

Figure 1: Tumor patient data (anaplastic ependymoma) a) CE image, b) FLAIR c) APT, d) EPT. APT and EPT both show elevated values in the tumor, but yield independent contrasts

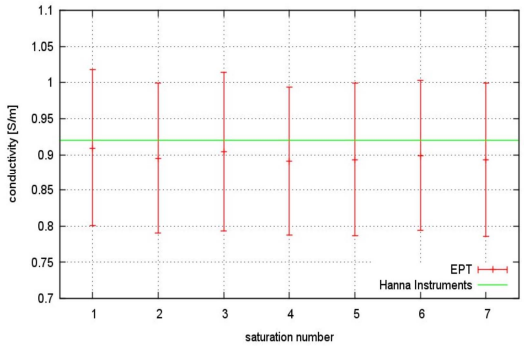

Figure 2: Conductivity measurements based on EPT (red) are independent of the offset frequency of the APT saturation pulse and consistent with the independent measurement by an external device (green).

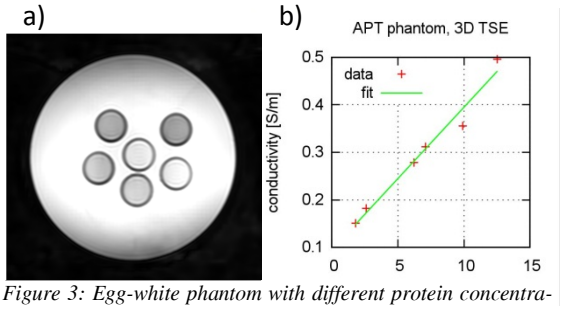

Figure 3: Egg-white phantom with different protein concentrations a) was used for assessment of combined APT and EPT reconstruction from the same imaging sequence. b) MTR asymmetry and electric conductivity of the probes show a linear dependence.

Conclusion:

The basic feasibility of 3D FSE sequence for the simultaneous acquisition of APT and EPT contrasts was demonstrated.

References:

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