2D Chemical Shift Imaging of hyperpolarized isotopically enriched ^{129}Xe within human brain

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Introduction

Due to the high solubility of xenon in blood and tissue, hyperpolarized ^{129}Xe (HpXe) MR measurements in various organs are becoming more and more interesting. Besides the diffusivity of lung parenchyma [1] and the perfusion of the heart and kidney [2], brain perfusion is one of the most interesting physiological parameters accessible with HpXe [3-5]. The high sensitivity of the ^{129}Xe resonance frequency to the molecule/tissue HpXe has bound to gives hope for a specific probe [6].

Methods

For polarizing ^{129}Xe (natural abundance, or isotopically enriched) by spin-exchange optical pumping [7] a home-built flow system [8] was used. About half a liter of HpXe gas (normal conditions) was accumulated as ice in the LN trap and thawed to fill a detachable Tedlar™ bag (GSTP001-0707, Jensen Inert, Coral Springs, USA). ^{129}Xe polarizations of 12-18% were routinely achieved.

All MR measurements were performed on a 3 tesla scanner (MedSpec 30/100, Bruker Biospin MRI, Ettlingen, Germany) using a commercial double-resonant ^{1}H/^{129}Xe open birdcage head-coil (Rapid Biomedical, Würzburg, Germany).

By phantom measurements using a glass bulb (2 cm diam.) filled with HpXe (natural abundance) the spatial distribution of the B_1-field was investigated. Loading the head coil with a hollow cylinder (14 cm inner diam.) serving as tissue equivalent phantom, 20 consecutive FIDs (RF pulse repetition time Δt=3 s) were measured with the glass bulb positioned at 25 different sites in the x-z-plane within the loading phantom. To determine the average flip angle α the decaying amplitudes were fitted to $\cos^n\alpha$.

In 2D-CSI measurements 15 seconds prior to starting the MR sequence the volunteer inhaled the HpXe (isotopically enriched to 82% ^{129}Xe) and held breath until the end of the scan lasting 15 seconds. The 2D-CSI sequence was modified to account for the needs of Hp-gas imaging. Due to the decay in polarization and hence loss in signal intensity by each RF excitation the *k*-space was sampled in a spiral way starting from the center (*k*=0). By omitting the outer corners of the 16x16 matrix a reduction of the acquisition time to 3/4 was achieved without appreciable loss of information.

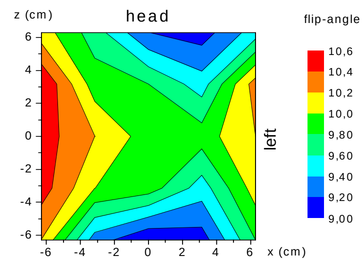

Figure 1: Distribution of flip angle for the ^{129}Xe channel within the head-coil.

The raw data were rearranged in a 16x16x1024 matrix and a 2D FFT was performed to get the spatial distribution of the FIDs. These FIDs were analyzed by a time-domain frequency-domain (TDFD) method fitting frequency, amplitude, linewidth and phase independently for each line within user adjustable constraints [9]. For each of the 256 spectra of a 2D CSI acquisition the measured spectra, the fitted spectra and the values for the fitted parameters are obtained. Using the amplitudes color encoded images of the intensities of the different lines are obtained and overlaid onto a proton image obtained in the corresponding orientation.

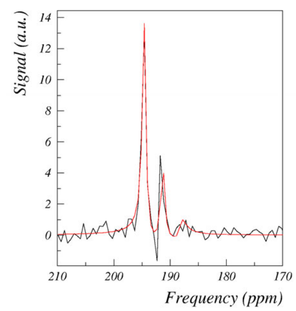

Figure 2: Single spectrum from a sagittal 2D-CSI measurement (black) with a fit of three lines (red).

Results

The flip angle measurements proved that the head-coil has a sufficiently homogeneous B_1-field distribution resulting in less than 10% variation of the adjusted flip angle within a concentric cylindrical volume of at least 12 cm in length and diameter (Fig. 1).

With the usage of hyperpolarized isotopically enriched ^{129}Xe the signal to noise ratio (SNR) of the resulting spectra from the 2D-CSI measurements (performed in sagittal, axial and coronal orientations) was substantially increased (Fig.2 black line shows real part) yielding SNRs >> 10 for the dominant line at 196 ppm. Now the second line at 192 ppm is clearly resolved. The third line at ~187 ppm is weakly seen in some of the spectra.

Besides the fitted spectrum (Fig. 2. red line) the TDFD method gives the amplitudes of the four lines at 0 ppm (corresponding to the signal from the gas phase), 186 ppm, 192 ppm and 196 ppm. In Fig. 3 these amplitudes of the four lines are imaged color encoded. Clearly the gas bag lying over the head of the volunteer was resolved. The image of the dominant line shows a uniform spreading over the brain in all orientations whereas the 186 ppm and 192 ppm lines are showing a more inhomogeneous distribution.

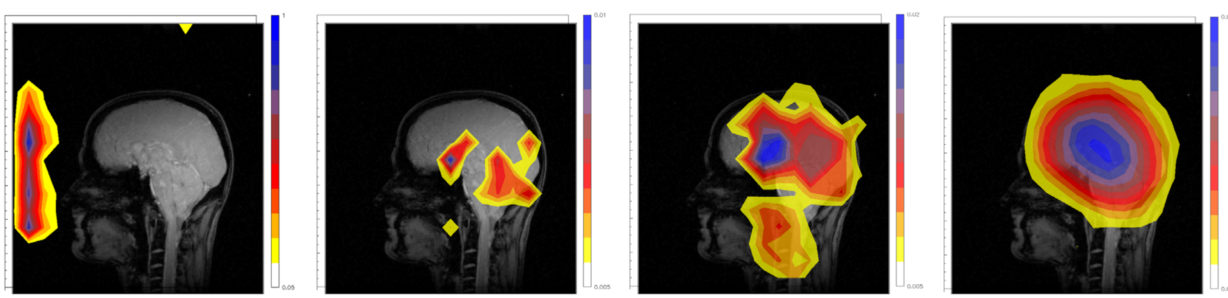

Figure 3: 2D-CSI image of HpXe (FOV 32 x 32 cm^2, 16 x 16 matrix, no slice selection): measured signal strength of the four resolvable lines at 0 ppm, 186 ppm, 192 ppm and 196 ppm (from left to right) are color encoded pictured with an underlying proton image of the corresponding orientation..

Discussion

With the usage of highly polarized isotopically enriched ^{129}Xe, a dedicated head coil for simultaneous ^{1}H/^{129}Xe measurements and a quantitative analyses of the obtained spectra we are now able to image the distribution of the different resonance lines in a routinely measurement protocol. Up to now we did not try to look for the blood peak at 215 ppm. Also the knowledge of the phase accumulation for the different lines were not implemented in the fit algorithm. After improving data analysis and achieving higher ^{129}Xe polarizations we plan to investigate changes in brain perfusion in patients.

References

1.Ruppert K. et al., *Mag. Reson. Med.*. **51**, 676 (2004)
2.Swanson S.D. et al., *Mag. Reson. Med.* **42**, 1137 (1999)
3.Choquet P. et al., *Mag. Reson. Me,*. **49**, 1014 (2003)
4.Kilian W. et al., *Mag. Reson. Med.* **51**, 843 (2004)
5.Proc. Intl. Soc. *Mag. Reson. Med.* **11**, 767, 768, 770 (2004)
6.Lowery TJ et al., *Magn. Reson. Imag.***21**, 1235 (2003)
7.Walker T.G and Happer W., *Rev. Mod. Phys.*, **69**, 629, (1997)
8.Kilian W., PhD thesis, Freie Universität Berlin, (2001): www.diss.fu-berlin.de/2001/105
9.Schubert F. et al., *Magn. Reson. Mat. Phys. Biol. Med.*, **14**, 213 (2002)