Optimization of Iterative Reconstruction for correlated ^{35}Cl- and ^{23}Na-MRI

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Target Audience: Clinicians and physicists interested in ^{35}Cl MRI and iterative reconstruction methods.

Purpose:

Chloride is the most common anion and thus involved in important metabolic processes. Studies confirm an altered concentration of chlorine in diseased tissue[1]. Due to the low SNR and short relaxation times of ^{35}Cl nuclei, ^{35}Cl-MRI plays a secondary role in functional imaging up to now. The in-vivo signal of ^{35}Cl is smaller by five orders of magnitude, ^{23}Na four compared to proton imaging. Therefore, special techniques such as the use of ultra-high-fields and iterative reconstruction are required to improve the image quality of ^{35}Cl– and ^{23}Na-MRI in order to get quantified statements in human tissue.

Methods:

Phantom- and in-vivo-measurements were performed on a 7T whole-body MR scanner (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) using a double-resonant (^{23}Na/^{35}Cl) quadrature birdcage coil (Rapid Biomed GmbH, Rimpar, Germany).

For the first time the reconstructions of ^{35}Cl-data were performed using an iterative Compressed-Sensing based[2,3] reconstruction algorithm (3D-DLCS)[4] in combination with a density-adapted 3D radial pulse sequence[5]. The measurement parameters were the following for an isotropic resolution of (5mm)^3[3]: TR=52.00ms, TE=0.6ms, α=90°, readout time T_{RO}=4.99ms, projections N_{proj}=1700 N_{av}=32. Parameter settings of ^{23}Na for correlation were: TR=160.00ms, TE=0.35ms, α=90°, readout time T_{RO}=9.98ms, projections N_{proj}=4000 N_{av}=1.

As a basis for an optimization of ^{35}Cl-MRI, simulated data were used[6] and the improvement compared to the standard reconstruction, the Nonuniform fast Fourier transform (NUFFT)[7], was analysed.

The quantification in human brain was achieved by gathering reference phantom measurements containing a model solution of 0.3-, 0.6-, and 0.9% NaCl placed in three different small tubes.

Additionally, one healthy volunteer (male, 30y) was examined and the ^{35}Cl-MRI was quantified and compared to the ^{23}Na MRI

Results:

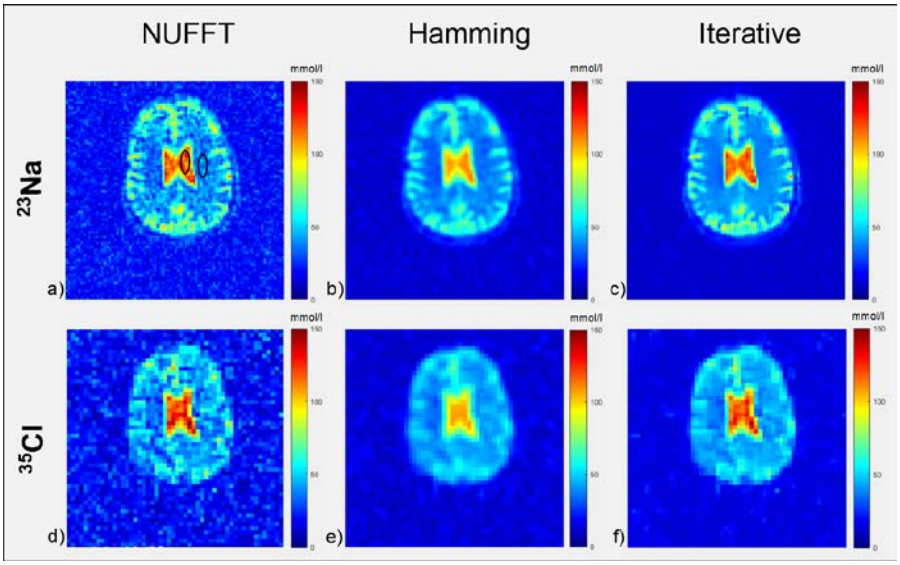
Thanks to the optimization of the iterative 3D-DLCS reconstruction algorithm for a resolution of 5mm (N_{proj}=1700, N_{av}=32) and parameter optimization (data consistency weighting λ= 4.5) a near optimal ^{35}Cl image quality was achieved.

Fig. 1 displays unfiltered and Hamming filtered NUFFT reconstructions, as well as the iterative 3D-DLCS reconstructions of both the ^{23}Na and ^{35}Cl images. The ^{35}Cl images display an increased concentration in white matter when compared to ^{23}Na while in CSF similar values are revealed.

Discussion and Conclusion:

In spite of the low signal intensity and the short relaxation times, ^{35}Cl-MRI allows the spatially resolved detection of the most common anion in the human body by using the 3D-DLCS algorithm in combination with a 3D radial sequence for the first time. The correlation to ^{23}Na-MRI demonstrates an increased concentration of ^{35}Cl in CSF and white matter. The increased spatial resolution is beneficial for diagnostic applications in tumor or muscle imaging.

Fig. 1: Comparison of ^{23}Na (a,b and c) and ^{35}Cl (d,e and f) regarding to the concentration of Na and Cl ions in human brain. The nominal resolution was (5mm)^3 for the ^{35}Cl data and (3mm)^3 for the ^{23}Na data



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