Quantitation of MRSI Data in the Presence of Magnetic Susceptibility Effects

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Introduction

Quantitation of MRSI data faces many problems, 1) field heterogeneities, 2) magnetic susceptibility effects, 3) Gibbs artifacts related to truncation of data in the *k*-space and/or time-domain. This study focuses on quantitation of MRSI data in the presence of susceptibility effects. Differences of susceptibility between adjacent media (bone/tissues, air/tissues) lead to field heterogeneities and attendant decreases of T_2* (increases of damping factors) of the metabolite signals thus hampering quantitation. Using simulated data, we study the effects of magnetic susceptibility on metabolite images. Quantitation is done using the time-domain quantitation algorithm QUEST [1]. We also study and evaluate the use of the estimated confidence bands based on Cramér-Rao lower bounds (CRBs) to detect relevant voxels.

Method

The effects of magnetic susceptibility on MRSI data were investigated by modelling the magnetic field map in the presence of adjacent media with different susceptibilities [2]. Our simulated phantom consisted of two cylinders perpendicular to a 1.5 T homogeneous magnetic field. The susceptibility in the inner cylinder, mimicking bone was χ_1 = -8 ppm; that in the outer cylinder, mimicking tissues was χ_2 = -11 ppm. These cylinders were immersed in air whose susceptibility is χ_3 = 0.36 ppm. The simulated signals in the outer cylinder contained water and, NAA, Choline (Cho) and Creatine (Cr) with concentrations (13:8:2) corresponding to a healthy adult human brain. They were quantum-mechanically simulated using a spin-echo sequence with TE = 136 ms and their damping factors α were assumed to be initially 10 Hz. The spatial distribution of the metabolite amplitudes was uniform.

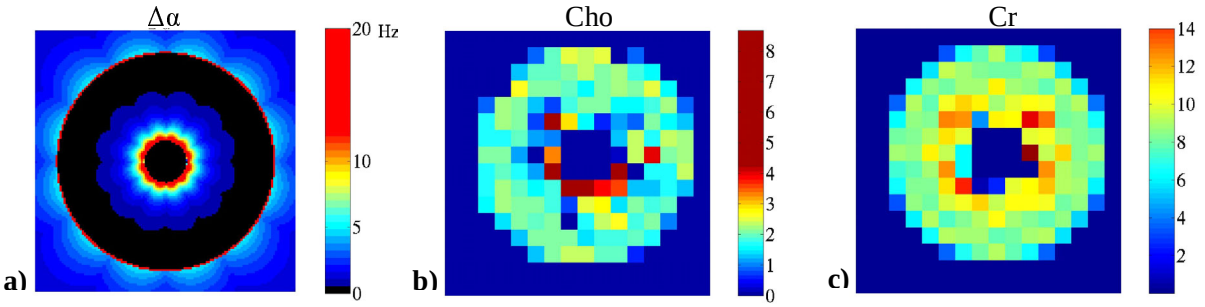
The magnetic field map was computed according to [2]. Computing the corresponding frequency-shift map is then straightforward. The $\Delta\alpha$ damping-factor increase map can be evaluated from the local magnetic-field heterogeneity map ΔB_{loc} computed from the magnetic field map, recalling the relation $\alpha + \Delta\alpha = 1/T_2^* = 1/T_2 + \gamma\Delta B_{loc}/2$. Finally, the MRSI data were simulated as follows:

1) Simulation of the 128 x 128 magnetic field map of the mentioned phantom.
2) Simulation of the 128 x 128 x 1024 matrix $A(x,z,t)$ corresponding to the susceptibility effects on the localized signals including the spatial frequency-shifts and increases $\Delta\alpha$ of the damping factors.
3) Simulation of the 128 x 128 x 1024 matrix $C(x,z,t)$ containing the localized metabolite signals as previously described.
4) Multiplication term by term of the *A* and *C* matrix elements.
5) 2D-FFT with respect to the spatial dimensions to obtain the MRSI data in the (k_x,k_y,t) space.
6) Truncation in *k*-space to get a 16 x 16 x 1024 matrix simulating the MRSI data in the presence of magnetic susceptibility effects.
7) 2D-FFT with respect to the *k*-space dimensions to get the localized signals to be quantitated.
8) Quantitation with QUEST, after water removal, of the localized signals and reconstruction of the metabolite images, frequency-shift and $\Delta\alpha$ maps.

The frequency-shifts can easily be corrected by QUEST itself or preferably in this case in a preprocessing step using MRSI water data. The increase of the damping factors of the metabolite signals related to magnetic susceptibility effects is a major problem. As shown in [3], the Cramér-Rao lower bounds, revealing the quantitation precision, strongly increase when the damping factors increase. Then, when half the confidence interval on a parameter (*i.e.* amplitude) becomes greater than the parameter itself, *i.e.* $p\text{-}2\text{CRB}_p \leq 0$, where the factor of 2 corresponds to a confidence level of 95%, the estimated parameter *p* is insignificant and quantitation is lost in advance for the considered metabolite. The lower bound of the Normalized Confidence Band, NCB = $1\text{-}2\text{CRB}_{am}/a_m$, on metabolite amplitudes a_m can provide insight about quantitation reliability in the voxels corrupted by magnetic susceptibility effects.

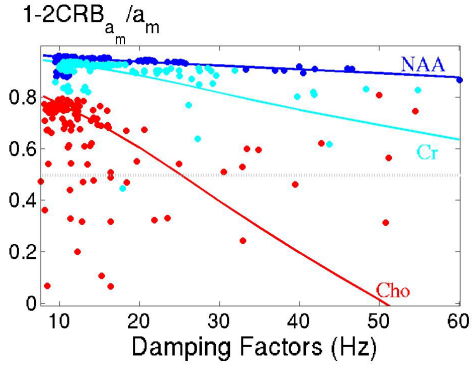
Results

The $\Delta\alpha$ map computed from the magnetic field map is given in Fig.1.a. Increases of α near adjacent media are clearly visible. The metabolite images of Cho and Cr, estimated with QUEST are displayed in Fig.1.b and c. The NAA image is less problematic and is not displayed. One can see that signals cannot be reliably quantitated at the interfaces between the different media. The graph represents plots of the estimated NCBs on metabolite amplitudes of NAA, Cr and Cho as a function of the estimated damping factors for all voxels (dots). Are also plotted the true NCBs (full lines) of these metabolites computed using the known concentrations (13:8:2) and the true $\alpha + \Delta\alpha$. Note that NAA can be successfully quantitated in all voxels; Cho can not, note the scattered Cho dots in the graph far from the true values.



Discussion

We believe that graphs based on *estimated* normalized confidence bands can provide valuable insight in distinguishing relevant voxels. However, estimated NCBs must be cautiously used because, 1) in the regions of strong susceptibility effects, they are calculated with parameters with large uncertainties and 2) the model function used in the CRB calculations does not account for the effects of *k*-space truncation. To avoid misinterpretation, relevant voxels should belong to 'NCB clusters'.



Acknowledgements

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