Localized Filtering for Optimal Fat Suppression in Parallel ^{1}H MRSI

Thomas Kirchner[1], Anke Henning[1], and Peter Boesiger[1]
[1]*Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland*

Introduction

Magnetic Resonance Spectroscopic Imaging (MRSI) avails of the chemical shift difference of nuclei, i.e. protons bound to different chemical compounds, together with phase-encoding to yield spatially and spectrally resolved information about metabolite distribution. Due to the low spatial resolution compared to imaging, a typical artifact encountered in MRSI is the voxel bleeding effect, which causes the spectrum in a given Voxel of Interest (VOI) to exhibit contributions from areas outside the VOI as expressed by the Spatial Response Function (SRF). A striking manifestation of voxel bleeding is subcranial fat signal falsely appearing in the center of the brain. Global fat suppression pre-pulses could in principle be used in the MRSI sequence to suppress these contributions. However, any wanted fat signal appearing e.g. in pathologies such as tumors would be lost as well. Selective excitation of the Field of View (FOV) for fat suppression e.g. by PRESS carries a strong chemical shift displacement effect, and is restricted to rectangular FOVs. ***In this work***, we introduce a novel local filtering technique that enables local voxel bleeding control and can be readily applied to SENSE-accelerated MRSI [1, 2, 3]. Fat artifact suppression is thus achieved selectively without introducing further artifacts or potential loss of spectral information.

Theory and Methods

Data acquisition: A spin echo MRSI data set with a 240 mm x 200 mm FOV (voxel size 10x10x10 mm^3) of a transversal slice of a healthy volunteer brain was acquired using an 8-channel head coil on a 3T MR system (Philips Medical Systems, Best, The Netherlands). The *TE* = 144 ms spin echo sequence with interleaved VAPOR water suppression and outer volume suppression (SELOVS [4]) resulted, at *TR* = 912 ms, in a total acquisition time of 7.5 min.

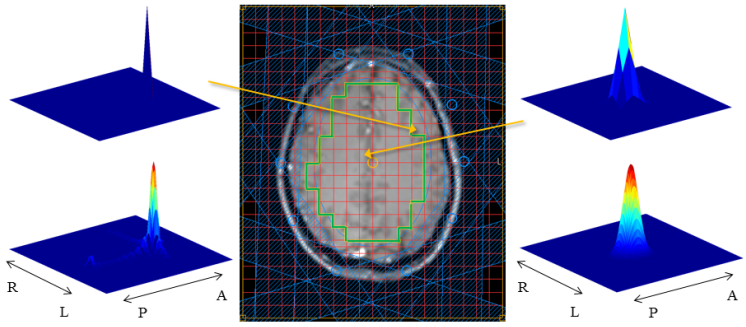

Figure 1: *Top: 2D target functions as assigned to inner-brain (right) and edge voxels (left), where the green division line is defined based on anatomical prior knowledge. Bottom: resulting SRF with the FWHM of the main lobe corresponding to the effective voxel size.*

Algorithm: We obtain the reconstruction matrix F required to perform SENSE unfolding by minimizing the cost function $\Delta_\pi = \|(FE - T)_\pi\|_2^2 + (F\Psi F^H)_{\pi,\pi}$ for all voxels π [5]. The second term containing the system's noise covariance matrix Ψ minimizes the noise level while the first term ensures an optimal shape of the SRF, which is the product of F with the encoding matrix E. Previous studies [6] corroborate that the choice of the target functions assembled in T as (*1*) a Dirac or (*2*) a normalized 2D Gaussian peak centered at the VOI leads to (*1*) far-reaching voxel bleeding as in standard SENSE and (*2*) efficient suppression of far-reaching voxel bleeding at the cost of a somewhat increased effective voxel size. Analytical investigation reveals that T effectively acts as a filter in real-space (that may also be employed in a frequency-selective way). In contrast to a global ***k***-space filter such as a Hamming window, direct local control over the SRF is thus enabled. Using anatomical prior knowledge, we assign the appropriate target functions to the individual VOIs as shown in Fig. 1. Raw data were extracted from the 8 channels along with the coil sensitivity information, and reconstruction was performed after introducing ***k***-space undersampling by removing every other Cartesian sampling point in both AP and RL direction, thus simulating 4-fold accelerated acquisition. This is equivalent to a mere 1.8 min acquisition time.

Results

Fig. 2 shows the reconstructed MRSI with (*a*) Dirac and (*b*) Gaussian target functions uniformly assigned to the entire FOV. The former displays strong fat contaminations, overlapping with the NAA peak due to shim imperfections. In the latter case they are reduced at the cost of a considerable fat spread at the edge of the object (indicated by arrows). This is due to the increase of the effective voxel size and compromises spectral quality in the brain matter voxels immediately adjacent to the fat region. In (*c*), a locally discerning choice of target functions as illustrated in Fig. 1 leads to an appealing result, with fat spread minimized at the edge as well. The set of spectra in (*d*) was Hamming-filtered: Although smaller than in (*b*), an increased edge fat spread compared to (*c*) is still visible.

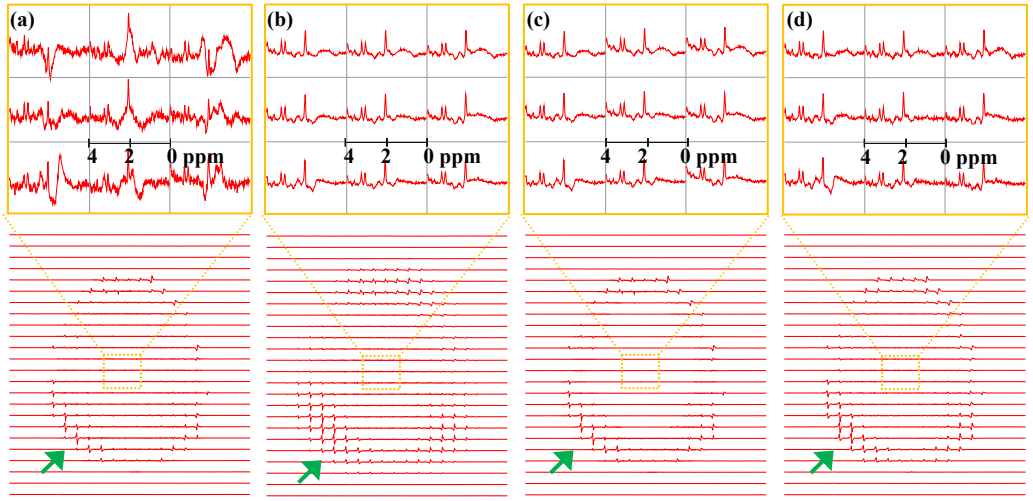

Figure 2: *Reconstructed real spectra from 4-fold undersampled MRSI with* (a) *Dirac,* (b) *Gaussian and* (c) *mixed target as in Fig. 1 SRF target.* (d) *is a Hamming-filtered version of* (a) *for comparison. A 2 Hz exponential noise filter was applied after HLSVD residual water subtraction. Scaling is identical among the four enlargements.*

Conclusion

We tailored SENSE reconstruction for MRSI by introducing local SRF target filters. We demonstrate efficient suppression of artifacts caused by subcranial fat in the center of the brain while at the same time minimizing fat signal spread at the edge of the object. Full information about the signal origin at each voxel is retained as it is essential for quantitative metabolite studies. This provides a unique advantage over conventional global ***k***-space apodization techniques like Hamming filtering for rapid proton MRSI *in vivo*.

References

[1] KP Pruessmann *et al.*, MRM **42** (1999) 952-962
[2] U Dydak *et al.*, MRM **46** (2001) 713-722
[3] J Sánchez-González *et al.*, MRM **55** (2006) 287-295
[4] A Henning *et al.*, MRM **59** (2008) 40-51
[5] KP Pruessmann, US patent No. 7.342.397
[6] T Kirchner *et al.*, Proc. ISMRM **19** (2011)