Parallel Spectroscopic Imaging

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Although clinical interest in MR spectroscopy has increased significantly during the past years, multi-voxel approaches such as MR spectroscopic imaging (MRSI) are usually still restricted to low spatial resolution and single slice measurements in clinical practice. Enabling whole brain coverage with high resolution by developing fast MRSI techniques therefore remains a promising challenge.

Combining the approach of sensitivity encoding (SENSE) with MRSI has proven to be an efficient match [1]: With two phase encoding dimensions 2D MRSI can easily profit from high sense reduction factors. Furthermore no restrictions in the choice of parameters, such as echo time, bandwidth or spectral resolution, apply for the spectroscopic measurements. Last but not least sensitivity encoding can be combined with other fast MRSI techniques to enhance the imaging speed even more [2].

During the past five years it was shown that sensitivity encoded spectroscopic imaging (SENSE-SI) is a feasible approach for fast MRSI of the brain *in vivo*. Compared to conventional MRSI a scan time reduction of four is readily achieved. The combination of SENSE with multi spin-echo MRSI even allows for up to ninefold shorter scan times at 1.5 T. Using multi spin-echo SENSE-SI at higher field strength is especially promising, as the linear increase in spectral separation between the peaks may be traded for shorter sampling times of each spin-echo and thus an increase of the possible spin-echo train length can be achieved. While MRSI matrices of 16x16 still rule today's clinical practice, this new technique allows scan times of e.g. less than one minute for the acquisition of MRSI data with 24x24 voxels (Fig.1). Examples of this ultra-fast technique from healthy volunteers and clinical cases will be presented. However, also the difference between nominal and effective spatial resolution in this ultra-fast approach, due to the point spread function, will be addressed.

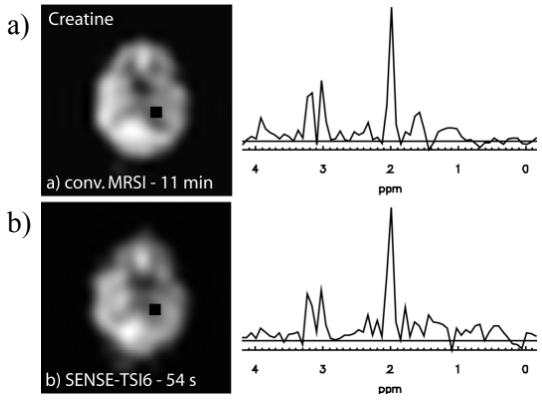

Fig. 1: Creatine maps and example spectrum acquired at 3T (24x24 matrix) (a) with conventional MRSI in 11 min and (b) with SENSE-SI with a multi spin-echo train length of six in 54 s.

Achieving such ultra-short scan times requires a trade-off with signal to noise ratio, which is not always affordable. Therefore, a more important achievement of SENSE-SI is the fact that it allows for multi-slice and whole brain acquisitions with good anatomical coverage in all three dimensions within scan times reasonable for patient measurements. As brain lesions are usually three-dimensional, a good spatial resolution in all three dimensions is important, as will

be demonstrated by a clinical example. Furthermore, 3D MRSI allows enhancing the SNR lost by reduced k-space sampling and enables MRSI scans with eight highly resolved slices within 20 min even at 1.5T (Fig.2).

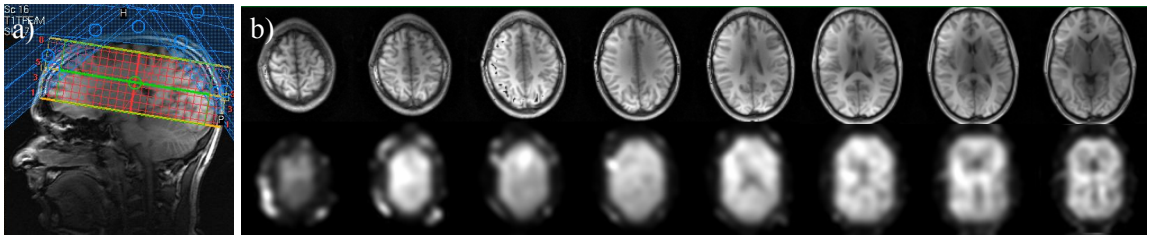

Fig 2: a) Setup of a 3D SENSE-SI scan with 8 slices at 1.5T. b) NAA-maps of 8 slices of a healthy brain with high spatial resolution (0.5 ml, 24x24 voxel per slice), acquired within 20 min (instead of 80 min with conventional MRSI).

Although SENSE reconstruction for MRSI data is more or less identical to Cartesian SENSE MRI reconstruction, special attention needs to be paid to the spatial response function (SRF). In low resolution imaging the SRF is much more critical and can lead to significant artifacts in sensitivity encoded spectroscopic imaging. By adequate extrapolation of the SENSE reconstruction such artifacts can be reduced.

Recently two new reconstruction approaches have been developed, which aim at optimizing the SENSE-SI reconstruction with regard to the poor SRF and the low through-plane resolution. The approach by Zhao et al. is an iterative reconstruction [3]: An intermediate unaliased dataset is reconstructed in a first step and used for optimizing the sensitivity maps with respect to reducing the mismatch between the assumptions made for the reconstruction model and the measured data. Another approach, by Sanchez et al., is based on optimizing the SRF at higher resolution than present in the final MRSI data [4].

In the future, new multi-channel capabilities on clinical scanners allow endeavoring 3D MRSI with SENSE reductions in all three dimensions, hopefully enabling true high-resolution whole-brain MRSI. With this promising outlook parallel SI remains to be validated for quantitative clinical use. Finally the ability to process, visualize and quantify thousands of spectra, acquired within only a few minutes, still remains one of the greatest challenges.

References:

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