3D SENSE Spectroscopic Imaging with Acceleration in Three Dimensions

U. Dydak[1], C. Possanzini[2], S. Kozerke[1], M. Kruiskamp[2], D. Meier[1], R. Luechinger[1], P. Boesiger[1]

[1]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland, [2]Philips Medical Systems, Best, Netherlands

Introduction

Applying sensitivity encoding (SENSE) to MR spectroscopic imaging (MRSI) has proven particularly advantageous to reduce scan time, as the two phase encoding dimensions in 2D MRSI allow for SENSE acceleration factors in two dimensions [1]. So far data from SENSE-MRSI measurements have been reported with a reduction factor of at most two in each phase encoding dimension [1-4]. Limiting factors were the signal-to-noise ratio (SNR) and/or the lack of appropriate coil arrays.

3D MRSI is a sequence with three phase encoding dimensions and furthermore offers an increased SNR compared to multi-slice techniques. Therefore it is an interesting candidate for SENSE acceleration in three dimensions. In this work a 16-element coil array with different coil sensitivities in all dimensions was used to test the feasibility of 3D SENSE-MRSI with acceleration factors of 2x2x2. In addition SENSE-SI with factors of 2x2, 2x3 and 3x3 are compared to conventional MRSI for single slice measurements.

Materials and Methods

All data were acquired on a 3T Philips Achieva whole body scanner (Philips Medical Systems, Best, The Netherlands). An experimental Philips neurovascular coil array was used, with 16 elements arranged in a way to allow for a SENSE factor of three in each direction. This coil has been optimized for brain and neurovascular imaging in terms of SNR, SENSE-capability and patient comfort and has been approved for in vivo applications. In a first step 2D MRSI data (slice thickness 15mm, 20x20 voxels, voxel size 1.5ml, TR/TE = 1500/144ms) was acquired in the brain of a healthy volunteer. SENSE factors of 1x1 (no SENSE), 2x2, 3x2, 2x3 and 3x3 were compared in terms of scan time, creatine/NAA ratio and SNR.

Furthermore, 3D MRSI data covering 20x20x12 voxels (TR/TE = 1500/144ms) was acquired with a spherical k-space shutter and SENSE reduction factors of 2x2x2 both in a spherical phantom (Ø≈15cm) containing choline (Cho), creatine (Cr), NAA and lactate as well as in the brain of a healthy volunteer. In the phantom the covered FOV was 200x200x180 mm, whereas voxels were three times smaller in vivo (FOV = 200x200x60).

Results and Discussion

Scan times of the 2D MRSI measurement were reduced from 9:16 min (1x1) to 2:24 min (2x2), 1:28 min (3x2) and even to 53s (3x3). All NAA maps in figure 1 show the same residual subcutaneous fat signal in the lower left corner of the image. This unsuppressed lipid signal demonstrates the good quality of SENSE reconstruction without aliasing, even for data acquired with a SENSE factor of 3x3. Cr/NAA ratios range from 0.26 to 0.31, except for the 3x3 acceleration case, where SNR becomes too poor for quantification of the spectra. For the middle voxel SNR drops from 9.43 (1x1) to 1.72 (3x3), whereas it drops less (from 8.31 in the 1x1 case to 3.54 in the 3x3 case) for a voxel in the periphery, where the coil has a higher sensitivity. However, as can be seen in figure 1, a maximal reduction factor of 2 should be used in each dimension, still yielding a fourfold scan time reduction, for this setup and coil for adequate spectral quality.

Figure 2 shows the successful reconstruction of eight-fold undersampled 3D MRSI data of the phantom. Spectra outside the object show no signal, whereas voxels inside the phantom show a quite constant signal as expected. While a conventional 3D MRSI exam with 20x20x12 phase encoding steps would be impossible to perform in vivo due to its scan time of 2h, a SENSE factor of 8 together with the spherical k-space shutter reduces the scan time to only 9:45 min (including the acquisition of water spectra for B0 correction). Although the in vivo 3D MRSI data showed rather poor SNR due to the small voxel size (0.5ml) and short acquisition time, SENSE-MRSI with acceleration in three dimensions shows great potential to be optimized regarding number of averages, voxel size and number of slices for brain applications, while scan times can be maintained in an acceptable range. Further improvement can possibly be achieved with coil arrays optimized for SENSE spectroscopic imaging of the brain (much smaller coverage in feet-head direction) rather than neuroimaging, esp. regarding dimension and coverage of the coil elements. Challenges for high-resolution 3D-MRSI of the brain remain the SNR of small voxels, a good fat suppression over the whole skull as well as good shimming over the whole brain.

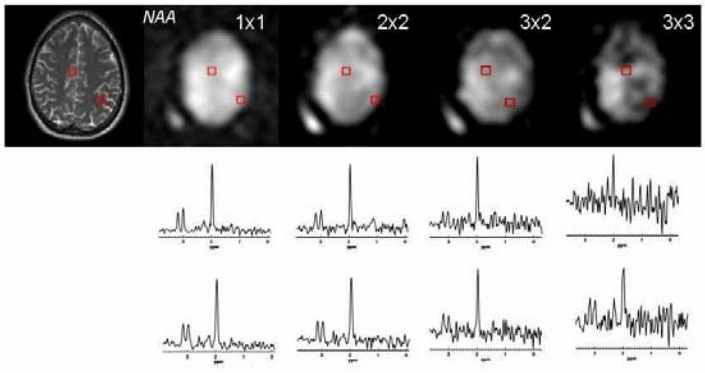

Figure 1: *2D MRSI results with different SENSE acceleration factors: NAA maps and spectra from the outlined voxels (upper spectra stem from the middle voxel, lower spectra from the peripheral voxel).*

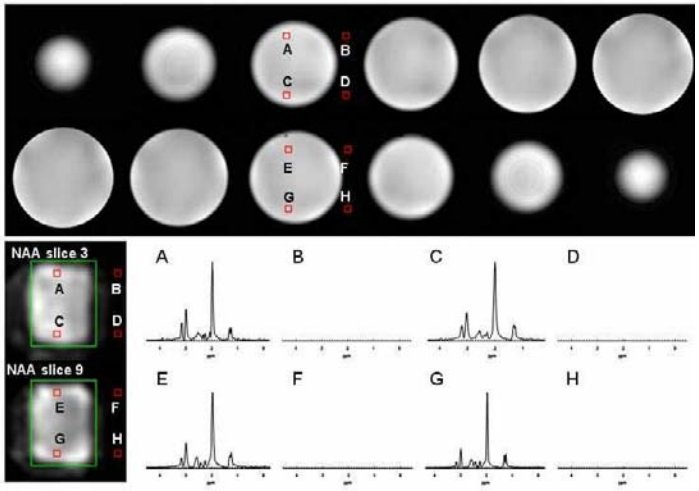

Figure 2: *3D MRSI data (spherical phantom, 12 slices) acquired with SENSE acceleration factor of 2x2x2: Spectra A-H show an example of eight spectra correctly reconstructed from an eightfold undersampled dataset. The NAA maps of the corresponding slices are shown on the left with the PRESS volume indicated in green.*

References

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