A 3D-PRESTO-SENSE sequence with UNFOLD and partial fourier encoding for fast susceptibility-weighted MRI

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INTRODUCTION:

MRI-sequences for functional-BOLD imaging and bolus tracking require a high temporal resolution while maintaining large brain coverage.
Although multislice, single-shot EPI are widely used in this role, often in conjunction with parallel imaging techniques like SENSE[1], the acquisition scheme of the 3D-PRESTO[2] sequence offers the advantage of maintaining long effective echo-times, while exploiting the maximum available imaging time.
In combination with SENSE and partial fourier acquisition schemes, PRESTO sequences can reach imaging times of 0.5s per volume and maintain full head coverage (isotropic resolution of 4mm)[3]. The aim of the presented feasibility study is to extend this idea by combining the UNFOLD[4] method, the SENSE method and a partial k-space sampling scheme with a 3D-PRESTO sequence.

METHODS:

Experiments were performed with a six channel headcoil on a Philips 1.5T Intera with explorer gradients (Gmax=23mT/m, slew rate S=120T/ms).
Imaging parameters:
FOV = 256x 205x 120mm^3, matrix=64x 52x 30, resolution = 4mm isotropic, flip angle = 11^o, water-selective excitation (1-2-1 binomial RF-pulse), $Bw_{readout}$ = 3.5KHz/line, 3D encoding direction: left-right, EPI-readout direction: anterior-posterior, fast phase encoding (EPI-blip) direction: head-foot. A navigator-echo prior to each readout train was employed to achieve a higher temporal stability of the 64 aquired volumes.

- PRESTO: TE_{eff}=41ms, TR=27ms, EPI readout of 31 lines, T_{AQ}/3D volume=1.6s.
- PRESTO with SENSE-factor 2 (in 3D enc. dir) and UNFOLD-factor 2 (in EPI readout dir): TE_{eff}=30ms, TR=18ms, EPI readout of 15 lines, T_{AQ}/3D volume=540ms.
- PRESTO with SENSE-factor 2 and UNFOLD-factor 2 and 70% partial-k space sampling (in 3D enc. dir): TE_{eff}=30ms, TR=18ms, EPI readout of 15 lines, T_{AQ}/3D volume=350ms.
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Image Processing:
All images were reconstructed off-line using the standard reconstruction schemes for SENSE and UNFOLD and the Cuppen method for full k-space restoration.

RESULTS:

Image set a) shows a sagittal and transversal slice of a healthy volunteer obtained with the standard 3D-PRESTO sequence with a temporal resolution of 1.6s per volume.

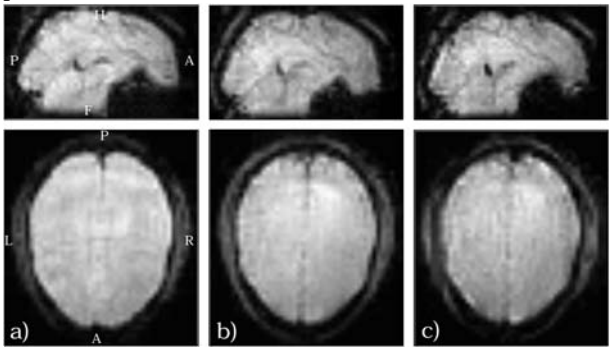

Image set b) shows the same slices obtained with a 3D-PRESTO sequence in conjunction with the SENSE and UNFOLD methods. Since the UNFOLD method is used to shorten the EPI readout-train by a factor of 50%, geometric distortions are reduced and the spatial resolution in HF-direction is visibly improved, although T_2^*-weighting is slightly reduced.
Image set c) shows the combination of 3D-PRESTO with SENSE, UNFOLD and an additional 70% partial k-space sampling. For the later method the LR-direction is choosen in order to provide partial k-space planes for the Cuppen-reconstruction that are obtained at the same point of the T_2^*-evolution during the acquisition train.
Despite the inevitable artefacts introduced by partial k-space sampling clearly depicted at the level of the lower temporal lobes, the sequence shows a sufficient SNR and an acceptable level of additional distortions/ghosting in comparison to the other sequences.

DISCUSSION/CONCLUSION:

3D-imaging methods like 3D-PRESTO for fast susceptibility-weighted MRI offer the flexibility to use a combination of multiple fast imaging techniques in more than one direction in order to shorten acquisition trains and to accelerate the total data acquisition without significant loss of T_2^*-weighting. In presented feasability study, the combination of SENSE, UNFOLD and partial k-space sampling with the PRESTO sequence offers the possibility of sampling susceptibility weighted whole brain volumes on a clinical 1.5T system within 350ms. Although the principal temporal resolution limits of the UNFOLD method apply[4], the high temporal resolution suggests the proposed sequence as an interesting candidate for bolus-tracking perfusion and event related fMRI studies.

1. Prussmann et al. MRM 1999;42:952-962
2. Liu et al. MRM 1993;30:764-768
3. Klarhoefer et al. MRM 2003;50:830-838
4. Madore et al. MRM 1999;42:813-828