Multi Slice Localized Parallel Excitation for Abdominal and Pelvic EPI Applications in Humans

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Introduction

Echo-planar imaging (EPI) is an advantageous MRI method due to its fast scanning speed and ability to image rapidly changing physiologic processes [1]. However, high sensitivity to B0 inhomogeneities and long minimum echo times (TE) have so far prevented the widespread use of EPI with high resolution for medical assessment of abdomen and pelvis and have limited its primary use to brain imaging. Global shimming in the abdomen and pelvis is very prone to local B0 deviations, leading to strong distortions in organs such as liver and prostate (Fig. 1); local shimming has the drawback that outer distortions can overlap into the region of interest. These artifacts may be particularly severe in abdominal and pelvic diffusion-weighted imaging (DWI), despite of numerous and sophisticated correction algorithms, which have been developed.

The recently introduced technique of parallel transmission made spatially selective excitation (SSE) applicable for realistic MRI protocols [2-4]. In the multi slice DW method presented for rodents in [5] parallel transmit SSE was combined with a reduced field of view (FOV) in the phase encoding (PE) direction and allowed a significant reduction of echo train length in EPI. Thus a transition from a conventional 4-shot EPI scheme to single-shot scanning with high resolution was achieved, minimizing ghost artifacts arising from inconsistencies between the shots.

The purpose of this work is to adopt this method for TE reduction and artifact suppression in EPI on a human scanner and thus examine application of 2D pulses in combination with a reduced FOV in the PE direction for multi slice DWI in the abdomen and pelvis.

Methods

The experiments in this study were done on a 3T human MR scanner (Siemens MAGNETOM Trio, A Tim System) with an 8 channel TxArray extension and an 8-channel parallel transmit body coil.

As described in [5], in order to keep magnetization from saturation in SSE with multiple repetitions, the following multi slice inner volume imaging (IVI) method was implemented. In this algorithm a set of parallel bands, limited in the PE direction of subsequent EPI read-out and confining a region of interest (ROI, Figs. 2, 3A), is excited so that every band extends across the whole object along the frequency encoding (FE) direction. This is achieved by putting one of the gradients of the selective excitation on the slice axis (Fig. 3B). The bands are refocused in the slice direction; herewith the refocusing frequency matches the band shift from the center along the slice direction. The imaging plane is thus the FE-PE plane which is perpendicular to the one the ROI was defined in (Figs. 2, 3). In this manner a multi slice SSE-EPI method was adopted for imaging the layers limited in PE direction.

The 2D pulses were designed with the help of a small tip-angle algorithm combined with conjugate-gradient optimization using B1 maps for the central axial slice [6]. Previously used excitation spiral trajectories [5] had grid size 64×64 and allowed the minimum slice thickness of ≈5.8 mm with the system gradient limits. In order to further minimize the slice thickness without significant lengthening of the RF shapes, EPI trajectories were preferred and optimized at the expense of reducing number of PE lines to 16 and increasing number of FE samples to 128 (Fig. 4). The field of excitation (FOX) was 18cm×18cm. For conventional single-shot DW-EPI scans the acquisition matrix was 128×128 with FOV of 18cm×18cm and minimum TE of ≈130 ms.

The scanned objects were bundles of parallel fibers, fixed to Plexiglas frame, and placed inside a cylindrical container filled with water (Fig. 5). Water diffusion was thus restricted to the preferred diffusion along the fibers' direction.

Fig. 1. Coronal SE-EPI image of abdomen with residual distortions and ghost artifacts indicated by arrows.

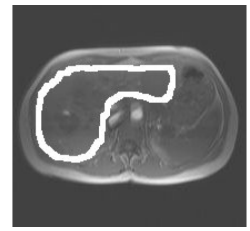

Fig. 2. Example of definition of ROI confining liver. The ROI is further cut into parallel bands, as shown in fig. 3A.

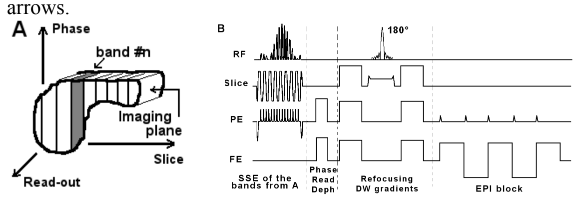

Fig. 3. Principle of the experiment. A. Sketch showing the bands to be excited. B. The corresponding sequence diagram. The 2D selective pulse in every TR corresponds to a new band from A.

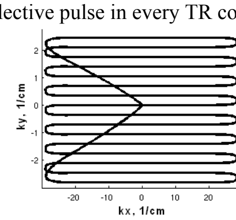

Fig 4. The optimized EPI trajectory used in the experiments had only 16 lines in PE and 128 samples in FE

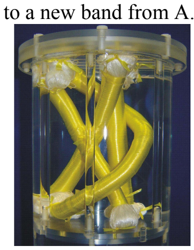

Fig. 5. A photo of the phantom used in the experiments

Results and Discussion

Several slices of resulting ADC maps of the phantom's fiber tracks acquired with the presented method are shown in Fig. 6. A reduction of the FOV in the PE direction by a factor of 4 allowed the minimum TE to be reduced from 125 ms to 90 ms, thus shortening read-out duration of single-shot SE-EPI and minimizing distortions and ghost artifacts inherent in conventional DW EPI, with the spatial resolution being kept the same. As can be seen from the data presented (Fig. 6) this approach also produced images of acceptable quality.

The described optimization of k-space trajectory for excitation was demonstrated to allow for slices as thin as 2.8 mm which can be seen as an important advantage of adopting this type of imaging for pelvic and abdominal studies. Further trajectory optimization for better outer signal suppression can be achieved by varying EPI blip sizes in such a way that the lines are getting closer towards the k-space center for more efficient and robust shaped RF excitation. Finally, local shimming can also be applied for better distortion correction and ghost suppression in the method presented.

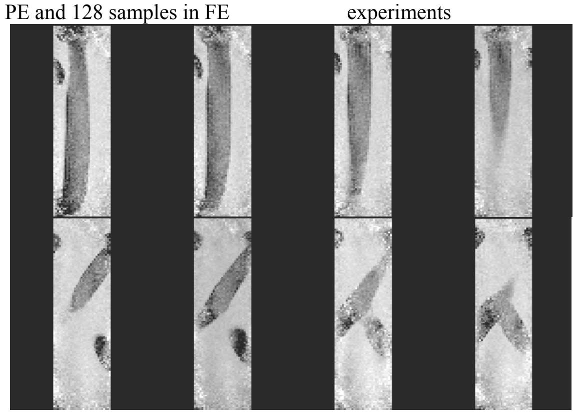

Fig. 6. Resulting sagittal ADC maps showing the fiber tracks. Slice thickness = 2.8 mm, FOV in PE was reduced to 4 cm and TE to 88 ms. Resolution matrix = 32×128 (PE×FE). Total number of bands excited = 20. Aliasing from imperfect suppression of signal outside the bands is very weak.

Conclusions and Outlook

Parallel transmission combined with a multi slice inner volume imaging algorithm was experimentally demonstrated in phantoms and gives advantage to novel applications of EPI. Abdominal and pelvic DWI is a clear example of the main principle of this method and its potential for future human studies, which will be undertaken once IRB for human applications of the TxArray becomes available.

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