Parallel Zoom EVI: effects of short TR on image quality

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Introduction

A new method has been introduced to perform single shot 3D imaging. It obtains high rates of acquisition (200ms/volume) on isotropic brain volumes (1). This method uses an EVI sequence, combined with outer volume saturation (OVS) pulses, and two dimensional parallel acquisition (with SENSE reconstruction), up to a reduction factor of 4. This paper presents the artefacts encountered due to the short repetition times reached and the solutions we used to correct for them.

Methods

Experiments were performed on a 1.5 T GEHC scanner (40 mT/m gradient, 150 T/m/s slew rate, 8 channel head coil array). The sequence and the reconstruction process have been described previously (1). On the first results obtained with this method, two artefacts have been identified, which result from the short Tr: unwanted signal residues in spite of OVS pulses and unevenness of the slice selection profile.

First, when saturation pulses were used with SENSE reconstruction, an horizontal slab in the middle of the volume always displayed poor image quality. This was due to insufficient suppression of the signal from the external areas. In fact, at small Tr, spins from the external areas are submitted to a rapid train of RF pulses. This train induces the formation of spin echoes and stimulated echoes of different phase pathways. Some of the magnetization components add up constructively to create a residual transverse magnetization once the steady state is reached. Then, the residual signal behaves like any other out of field of view signal: it generates an aliasing artefact. Moreover, this artefact appears in the middle of the field of view when R = 2 SENSE reconstruction is used (2). According to (3), we applied a quadratic phase modulation of the train of OVS pulses, with a 117° phase shift, and increased the crushers area to dephase these components more efficiently.

Second, when a flip angle of 90° is applied (like in EPI), the excitation profile along the partition direction displays a minimum in the middle of the excited slab, instead of the regular curve expected. Indeed, as our Tr are shorter than the T_1 of the brain tissues, a steady state is reached in which the signal is maximum for flip angles around the tissues Ernst angles (4). Consequently, this artefact is suppressed by choosing the flip angle equal to the minimum Ernst angle for our Tr. Furthermore, the signal is slightly increased.

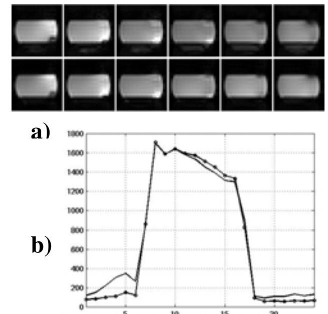

Figure 1 : a) 6 slices from sagittal EVI volume, TE/TR =78/200ms, BW=62.5kHz, FOV=140x140x84 mm^3, matrix acquired: 24x24x12. b) averaged profiles along the phase direction for the two volumes . a) and b) : no phase shift (up, solid line), 117° phase shift (down, circles).

Results

The above presented solutions have been applied to EVI zoomed volumes, with no parallel acquisition (R=1). Figure 1 shows a water phantom volume (long T_1) acquired with and without the phase modulation of the outer volume saturation pulses. The difference is slightly visible on this figure, but averaging the profiles along the phase direction on the whole volume shows a significant improvement of the suppression quality: from 11.2 % to 5.4 % of the averaged central signal. Figure 2 shows a volume acquired with 90° flip angle and with 35° flip angle (Ernst angle for Tr/T_1 = 200/1000 ms). The unevenness of the profile has clearly been removed, a change in contrast is also noticeable.

Finally, these two solutions have been applied to an acquisition with a reduction factor of 4, i.e. a reduction factor of 2 along both phase and partition directions. A sagittal brain volume acquired in 200 ms and the corresponding sensitivity map are shown on figure 3.

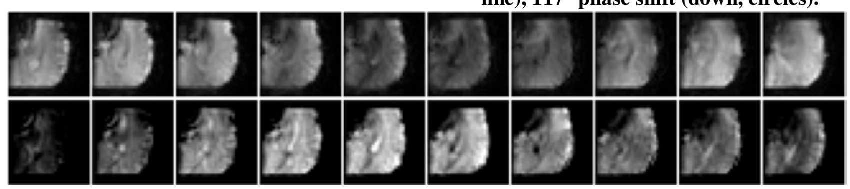

Figure 2: 10 slices from sagittal EVI brain volume, TE/TR=86/210ms, BW=62.5 kHz, FOV=140x140x84 mm^3, matrix acquired: 26x26x12, flip angles: 90°(up) , 35°(down).

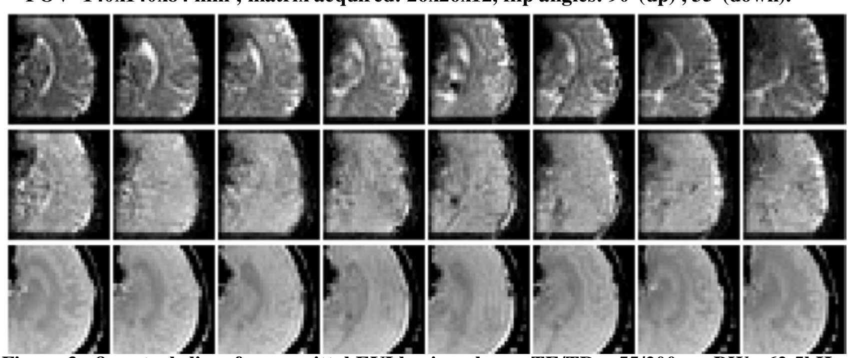

Figure 3 : 8 central slices from sagittal EVI brain volume, TE/TR = 55/200ms, BW= 62.5kHz, flip angle: 35°, FOV = 120x120x100.8mm^3, matrix acquired: 28x14x12, 32x32x24 effective matrix size after parallel reconstruction and interpolation. Up : third excitation, middle : steady state (after 10 Tr), down : sum of squares of the sensitivity map used for SENSE reconstruction (2D Gradient Echo).

Discussion

The two presented artefacts have been successfully corrected, allowing us to go on with the development of this method. Some fMRI tests on basic paradigms have been carried out and the results obtained are very encouraging. However, very locally, SNR seems lower. Because our head coil has not been optimized for 2D parallel imaging, its geometric factor may be responsible for that. To diminish this effect, a two stage reconstruction method has been implemented. The first stage uses a coarse voxel exclusion mask derived from the sensitivity maps in order to reconstructs the data. Then, a more accurate mask is calculated from the reconstructed data and used for the second reconstruction. Voxel exclusion has been shown to reduce the g factor values (4), and it improves our image quality but it has not, for the moment, suppressed this effect totally.

Another aspect of working with short Tr is illustrated on figure 4: after a few excitations, a steady state is reached in which the level of SNR is lower than in the first excitations. This must be taken into account when planning fMRI experiments, since only data from the steady state will be processed for activation detection.

Conclusion

This new zoomed parallel EVI method allows us to perform single shot acquisition of whole brain volumes, with high rates of acquisition (200 ms/ volume) and standard spatial resolutions. Future work will include non cartesian sampling, Bo inhomogeneity correction and geometric factor maps evaluation.

References :

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