Susceptibility-weighted imaging using unbalanced steady-state free precession gradient-echo imaging with multiple echoes

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Introduction

Susceptibility-weighted imaging (SWI) is now extensively used in clinical neural applications to enhance the depiction of vascular architecture for brain venography. [1,2] Traditional procedure of SWI uses the phase information from RF-spoiled gradient-echo (SPGR) image to calculate a phase mask for improving contrast of small vessel structure, which is subsequently applied to enhance the magnitude image. The aim of this study is to investigate potential benefits of multiple-echo acquisition [3,4] using the unbalanced steady-state free-precession (ubSSFP) sequence [5, 6] on SWI application, for its variety of image contrast and high SNR efficiency. We evaluate this proposed technique by analyzing the FISP and PSIF images obtained from ubSSFP sequence and comparing their image quality to a standard SPGR sequence.

Methods & Materials

We utilized both multiple-echo acquisitions of 3D ubSSFP (Fig. 1) and SPGR sequences under similar conditions to implement SWI. Three healthy volunteers were recruited and their MR brain images were acquired on 3.0 T platforms (Siemens, Erlangen, Germany) with a 32-channel head coil. Parameters for multiple-echo SWI scans were: TR= 35 ms, multiple TEs (longest TE was 33 ms for FISP, corresponding to shortest TE of 37 ms for PSIF; Fig.1), and flip angle (FA)=35 degrees. Furthermore, the number of echo pairs (four in Fig.1) could be adjusted with various echo spacings among the readout gradients. Voxel size was $1*1*2$ mm^3 and total scan time was about 10 minutes without parallel imaging acceleration.

The data processing included coil sensitivity combination with the 1st FISP image as a template. For phase unwrapping, the high-pass-filtered phase images were obtained by complex division of the original images and low-pass-filtered images. The SWI reconstruction was performed using Matlab (Natick, MA, USA), following the procedure described in [1].

Results

Compared with SPGR sequence, the ubSSFP applied on SWI technique shows diverse proton-density-weighted contrasts (Fig. 1, bottom) for the FISP series to various T2-weighted contrast for the PISF series, respectively. The late FISP (#8 in Fig.1) and the early PSIF (#1 in Fig.1) images showed similar phase evolution times (TE for FISP and 2*TR–TE for PSIF, respectively) to the SPGR image acquired at the same TE, hence serve as potentially suitable candidates for SWI-MR brain venography (Fig. 2). In analysis of imaging quality, the FISP images from the ubSSFP sequence have better SNR in the brain parenchyma than the SPGR counterparts.

Discussions & Conclusions

This work presents the possible use of ubSSFP sequence for SWI venography. Compared to SPGR, FISP series at similar TE in ubSSFP sequence is potentially beneficial in terms of SNR for visualizing the vascular architecture. The higher signal intensity of CSF in ubSSFP sequence facilitates minimum intensity projection (minIP), as opposed to SPGR where the dark CSF might obscure venous structures nearby. Multiple-echo acquisition, although not absolutely necessary for SWI, offers additional advantages in main magnetic field or T2* susceptibility mapping (not shown). It is concluded that the ubSSFP technique provides an alternative means for SWI-MR venography.
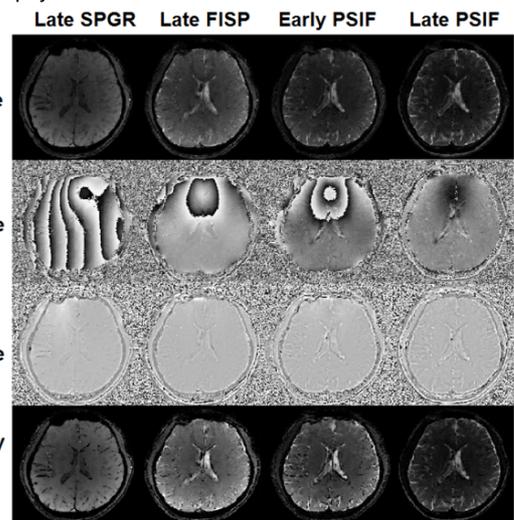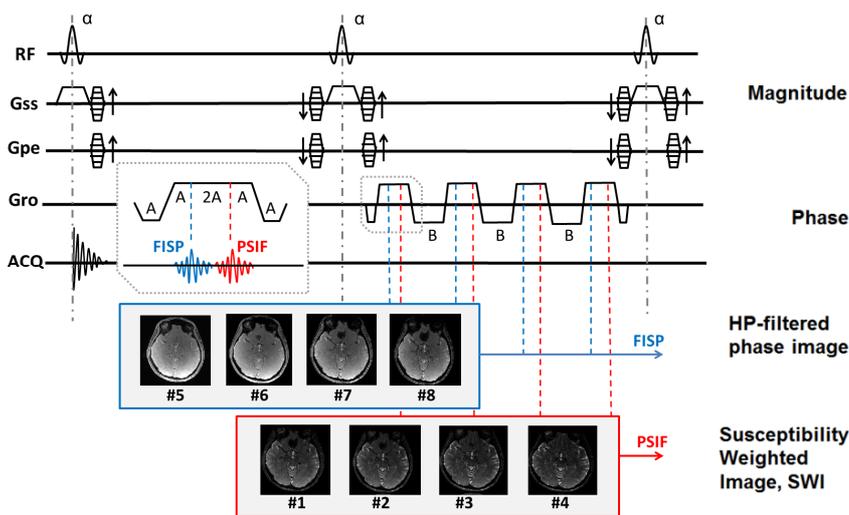

Fig.1 The pulse sequence diagram and echo formation of ubSSFP with asserted contrasts for brain imaging. A is the pre-phase gradient but otherwise B is the fly-back gradient for canceling the extra phase accumulation.

Fig.2 With the same subject, the magnitude, phase (wrap), High-pass -filtered phase images (unwrap) and SWI separately result from SPGR and ubSSFP sequences.

References

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