High-resolution non-contrast enhanced dark blood brain vessel imaging using a balanced steady state 3D projection reconstruction sequence

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INTRODUCTION

Balanced SSFP sequences have been used for non-contrast enhanced vessel imaging as blood signal is bright in SSFP images[1,2]. The dual-half-echo 3D Projection Reconstruction (3DPR) sequence has many advantages for SSFP imaging, including its high data acquisition efficiency and its capability to achieve short TEs and TRs [3]. However, as cerebrospinal fluid (CSF) signal is also bright in SSFP images, the application of this technique for vessel imaging in brain has been limited. In this work, we demonstrate that instead of appearing as bright signal, the vessels in the brain have low signal intensity in high-resolution 3T images. This provides a novel approach to achieve non-contrast enhanced high-resolution vessel imaging along with high quality T2 contrast images in 6 minutes at 3T with the dual-half-echo VIPR sequence.

MATERIALS AND METHODS

The dual-half-echo SSFP implementation of the multiple-echo VIPR sequence is shown in Fig. 1. Data acquisition begins immediately from k-space origin including all of their ramps. Each repetition acquires two half echoes at slightly different angles. Eddy current correction data on all 3 axes were collected and were used to measure the actual k-space trajectories and the phase accumulated due to B0 eddy currents [4]. These were then used to correct for both B0 eddy currents and linear eddy currents during image reconstruction.

Human studies were conducted on a 3T scanner (GE Healthcare, Milwaukee, WI) after consent was obtained. Imaging parameters included receive bandwidth =125 kHz, FOV = 22.4 cm in all three directions, flip angle = 25°, TR = 3.0 ms, TE1/TE2 = 0.22 ms/2.4 ms, image matrix = 448 × 448 × 448, and the image resolution is 0.5 mm isotropic. The total acquisition time is 6 minutes.

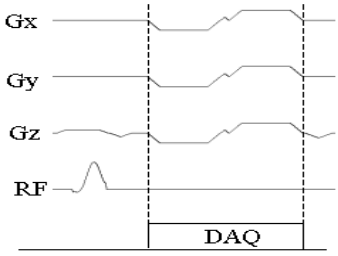

Fig. 1 Gradient waveforms of the dual-echo SSFP VIPR sequence.

RESULTS AND DISCUSSION

Representative high-resolution brain images of a healthy volunteer are shown in Fig 2. The rightmost image is shown in negative contrast. The isotropic resolution provided by the VIPR sequence allows the images to be reformatted in any plane for better visualization. The images show good contrast between CSF, gray matter and white matter. The vessels (arrows) show lower signal intensity than the surrounding tissues, especially CSF, and are readily visualized. In Fig. 3, the potential use of the SSFP sequence for vessel imaging is demonstrated in the minimal intensity projection images. Excellent depiction of the brain vessels can again be appreciated. As the T2 and T1 properties of the blood predict bright blood signal in SSFP images, the low signal intensity of the vessels is probably due to the effective frequency shift induced by blood flow to the SSFP stop-band.

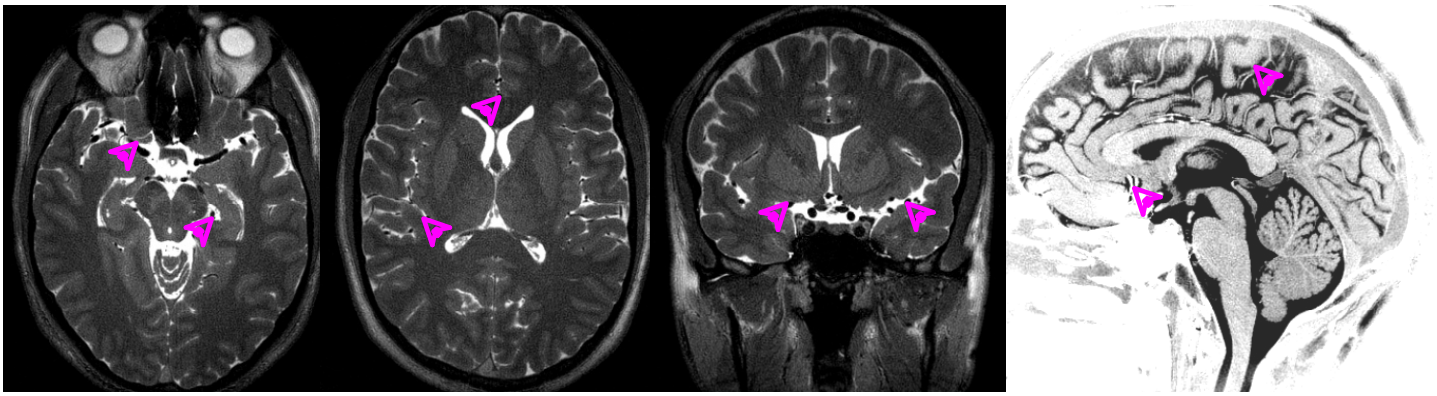

Fig 2. Representative images of a healthy volunteer collected with the dual-half echo VIPR sequence show good T2-like contrast (the rightmost image was shown in negative contrast). Brain vasculature visualized in excellent detail (examples are shown by arrows). The scan time was 6 minutes and the spatial resolution was 0.5 mm ×0.5 mm × 0.5 mm.

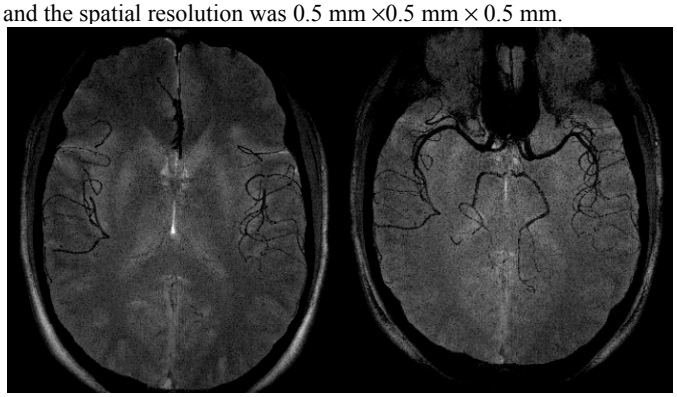

Fig. 3 Simple minimal intensity projections images show excellent detail of the vessels. The images are generated from the same dataset as shown in Fig 2.

CONCLUSIONS

The dual-half-echo SSFP VIPR sequence provides high data acquisition efficiency to allow high-quality high-resolution T2-like contrast images to be obtained in a relatively short scan time. The vessels in the brain appear dark in high-resolution 3T images, probably due to flow induced off-resonance effect. Our results demonstrate that non-contrast enhanced high-resolution vessel imaging can be obtained along with high quality images in 6 minutes at 3T.

REFERENCE

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