VIPR Steady State Imaging with Diffusion Sensitivity

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INTRODUCTION

3D projection reconstruction sampling methods have been useful in creating isotropic images at high resolution while also using short scan times. Previous implementations of Vastly undersampled Isotropic Projection Reconstruction (VIPR) [1] have provided T1-weighting (M^+ contrast) for contrast-enhanced MR angiography and T2-like contrast using truly refocused SSFP [2]. In this study, we investigated a VIPR sequence with M^- signal contrast. An additional diffusion-weighting gradient was also added to induce a sensitivity to water diffusion as reported by Buxton [3]. Whole-brain image volumes with isotropic image resolution (~ 1.2 mm) were acquired in roughly two minutes, with minimal artifacts in regions of high B_0 inhomogeneity.

MATERIALS AND METHODS

Imaging was conducted on a 1.5 T scanner (Signa Cvi; GE Medical Systems, Milwaukee, WI) with an 8-channel neurovascular phased array coil. To speed up acquisition, the VIPR imaging sequence, shown in Figure 1, uses multiple echoes to acquire 4 radial lines during each excitation. To image the M^- component, the slab-refocusing gradient was moved to the end of the sequence (just prior to the subsequent slab selection RF gradient). A dephasing, or diffusion-weighting gradient was added immediately after the slab selection gradient. The dephaser gradients can be applied in any arbitrary combination of x, y and z directions to make the sequence sensitive to diffusion in that direction. 3D PR images were acquired with a readout matrix equivalent to 256 x 256 x 256 over a 29 cm spherical FOV in a scan time of 60 seconds with a flip angle of 30°. Density compensation is performed to minimize the mean-square reconstruction error and minimize undersampling artifacts rather than maximize resolution [4]. The gradient dephaser duration is varied to create the desired b-values, according to

$$b = (\gamma G \tau)^2 TR ,$$

where γ is the gyromagnetic ratio, G is the diffusion-weighting gradient amplitude, and τ is the duration of the diffusion-weighting gradient. We created b-values varying from 1 s/mm^2 to 45 s/mm^2. Increases in dephaser duration caused increases in TR, which varied from approximately 6 ms to 18 ms for the b-values mentioned above.

RESULTS AND DISCUSSION

Example brain images obtained with this pulse sequence are shown in Figure 2. The contrast without the dephaser gradient has a very T2-w appearance (Fig 2a & b). The images in Fig 2c-e show the contrast with the application of diffusion-weighting gradients. As expected, small b-values (diffusion-weighting) create much higher diffusion sensitivity with this steady-state technique than is demonstrated with conventional spin-echo echo-planar techniques. In comparison with standard EPI DW images, there is no apparent image distortion in the brain above the sphenoid sinus (Fig 2c & d), ventral temporal lobe (Fig 2e) (near the inner ear) or the brain stem (Fig 2c-e). Since this is a true 3D acquisition, the images can be reformatted in any orientation without loss in apparent spatial resolution. Although this is a multi-shot diffusion-weighted sequence, no navigator correction was performed, although this may help to reduce certain motion artifacts. In general, projection reconstruction methods are less sensitive to motion artifacts.

CONCLUSION

The M^- VIPR sequence used in this study shows good results in areas of the brain that were previously difficult to image. Successes in imaging the temporal lobes, as well as above the sphenoid sinus give this technique an advantage over SE-EPI techniques that are commonly used in diffusion-weighted imaging. Potential applications of this method might include the localization and characterization of focal ischemic lesions, white matter disease and neoplasms in areas with strong magnetic field inhomogeneities.

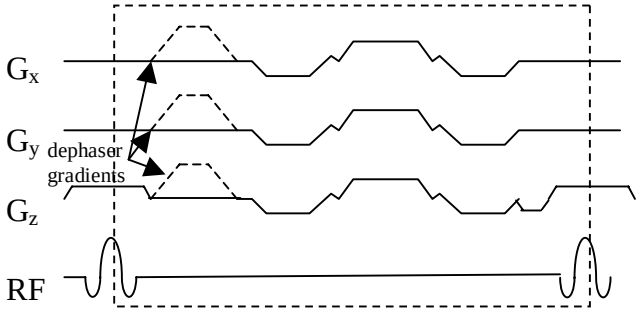

Figure 1. VIPR pulse sequence with M- data acquisition. The dephaser gradients may be turned on independently, as well as varied in duration in order to achieve the desired diffusion-weighting.

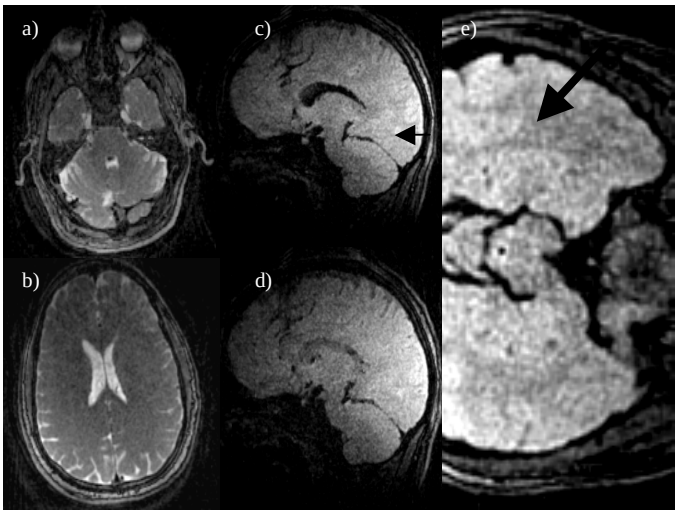

Figure 2. VIPR M^- images with no added diffusion-weighting are shown in a) and b). Note the high signal from the CSF, as well as the absence of B_o inhomogeneity induced artifacts near the sphenoid sinus. Diffusion-weighted images with weighting along the c)anterior-posterior direction and the d) right-left direction with b-values of 4.45 s/mm^2. e) An axial slice (with A-P diffusion-weighting, b=4.45 s/mm^2) taken from the location indicated by the arrow in c), shows the temporal lobes just above the sinuses. The arrow in e) indicates a 25% decrease in signal. The location is consistent with that of the white matter tracts of the temporal lobes. Again note the absence of artifacts near the sinuses.

REFERENCES

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