Trajectory-Corrected Dual-Echo PC VIPR Imaging at 3T

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INTRODUCTION

Non-Cartesian trajectories offer opportunities for accelerated imaging through higher-data collection efficiency and under sampling. However, this comes at the cost of increased artifacts from gradient errors, B0-inhomogenity and receiver delays. Several correction methods have addressed these errors; however current trajectory corrections techniques are inadequate for sequences with gradient encoded physiological information. In the case of Phase Contrast (PC) Vastly undersampled Isotropic PRojection (VIPR) imaging, each TR could have as many as five gradient pulses with amplitudes have been modulated with a non-linear relation to each other. We propose methods to correct these trajectories and present results.

THEORY

Trajectory corrections using the method proposed by Duyn et al [1] generally make measurements of a subset of the trajectories and assume missing measurements to be a linear combination of the measured. While effective in correcting standard VIPR trajectories [2], this method fails in cases where measurements are not linear combinations, as is the case for PC VIPR. We instead propose to characterize the trajectory as a linear combination of the responses from each individual gradient, with each trajectory measured by the Duyn method. In this case, we require the approximation that the gradients are a complete linear system.

METHODS

All experiments were performed on a clinical 3T scanner (GE Signa EXCITE2 Twinspeed). A sequence was initially implemented to test the linearity of gradient deviations, as measured by the Duyn calibration method. For simplicity, this was accomplished using two trapezoid pulses applied directly after on another, as shown in Figure 1. Trajectories were then measured using the Duyn method, with pulse A (first) alone, pulse B (second), and pulse A and B together. The measured trajectory of A and B was then compared to the sum of the trajectory deviations from A and B alone, for amplitudes and pulse widths covering those achievable in PC VIPR. This correction technique was then applied to a dual-echo PC VIPR sequence [3] as shown in Figure 1. Trajectories are calculated for every TR within the reconstruction as the sum of each pulse's relative magnitude multiplied by its measured trajectory. This accounts for different deviations for the different flow encodes. All gradient measurements were performed using 50 measurements per pulse per gradient direction, using a 60ms TR and 30º flip angle. PC VIPR acquisitions were acquired using typical acquisition parameters (9000 projections, 20x20x20cm FOV, 0.6mm isotropic resolution, 31.25 kHz BW, 50 cm/s VENC, 5:07 scan time). Off –resonance correction were performed using a multi-frequency recon using maps derived from the dual-echo data and a modified PILS reconstruction was used to reduce aliasing artifacts with coil sensitivities computed from low resolution data.

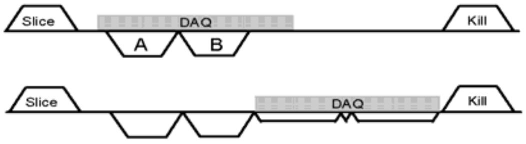

Figure 1. Calibration pulse sequences used for linearity test (top) and PC VIPR (bottom). Each gradient axis is similar.

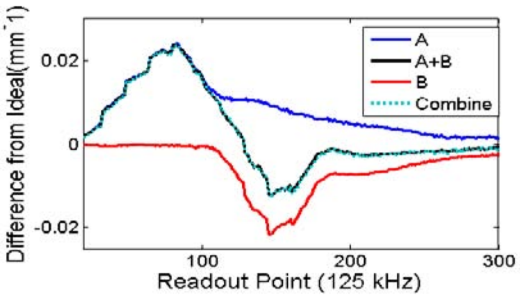

Figure 2. Trajectory errors of pulse A alone, B alone, both A and B, and the combination of the trajectory differences from A and B. This is an extreme case with the amplitudes set to opposite maximums and pulse durations of 300

RESULTS

Representative results of the gradient linearity tests are shown in Figure 2, with a comparison of the linear combination of the trajectory deviations of A and B verses the measured deviation with both pulses applied. The error of the linear sum is negligible with an average RMS error less than 0.1% of the max for all the measurements. A comparison of trajectory corrected and uncorrected speed images are shown in Figure 3. Corrected images show greater vessel conspicuity with fewer distortions. Corresponding MIP are shown in figure 4, with all of the correction measures applied.

DISCUSSION

The array of corrections utilized PC VIPR have allowed for high-resolution anatomical and flow imaging within reasonable imaging times. Trajectory correction are only one of many corrections necessary in the creation of images with not only better image quality, but also improved accuracy in the measurement of flow. We are currently investigating their utility for first-moment corrections, in which the measured flow encoding moment would be used to correct inaccuracies in the flow encoding on a per TR basis.

REFERENCES

1. Duyn *et Al*. JMR 132:150-153 ('98). 2. Lu *et A*l MRM 53(3):692-699 ('05)
3. Johnson *et Al* Proc 14th ISMRM ('05)

ACKNOWLEDGEMENTS

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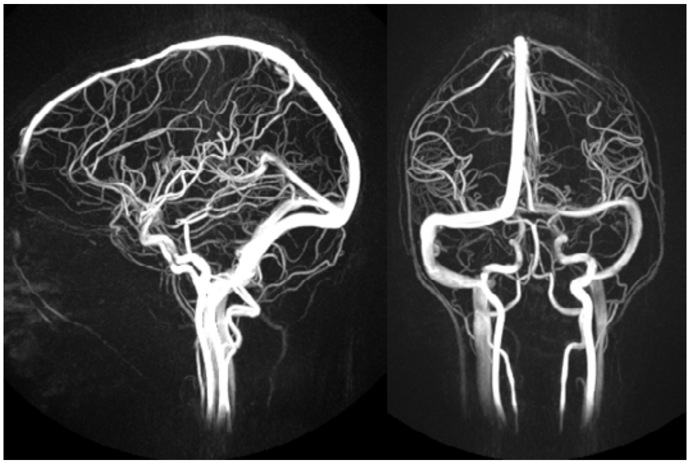

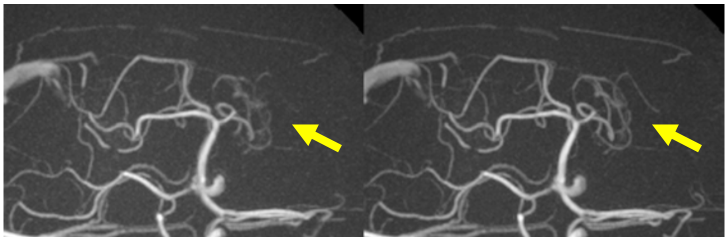

Figure 3. Limited MIP images without (left) and without (right) trajectory corrections. Images with corrections show significantly fewer distortions.

Figure 4. Volunteer MIP Images obtained using the dual echo PC VIPR sequence in 5 minutes. Note the unprecedented image quality and coverage for PC images.