Improved Body Phase Contrast imaging using a prospectively gated VIPR acquisition

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INTRODUCTION

We have previously shown PC VIPR to allow highly accelerated neurological phase contrast imaging, taking full advantage of the sparseness of the vasculature and spherical FOV [1]. The application of PC VIPR in other vascular territories has proved less successful due to the non-spherical FOV, motion corruption, and complex vasculature. To combat these we have implemented a self-calibrated radial optimized PILS reconstruction, a motion detection scheme with the possibility of correction, and a more optimal acquisition scheme. These techniques have allowed for accelerated phase contrast in vasculature territories including the renal arteries and cardiac applications.

METHODS

All experiments were performed on a 3.0T clinical scanner (GE Signa EXCITE2 Twinspeed). A prospectively gated sequence has been utilized, which allows for respiratory motion detection and possible correction, as shown in Figure 1. Projections are played in an interleaved fashion following the occurrence of an ECG trigger, with the overall trajectory determined by the total number of projections to be acquired and view ordering optimized to distribute projections pseudo-randomly along that trajectory. During the trigger wait time, projections are acquired along each of the three orthogonal physical gradients. These projections are stored for either projection rejection or correction in the reconstruction alone. For this study, rejection is only considered. Directly after the navigator, pulses are played to maintain magnetization and eddy-current steady state; no data is collected. All acquired projections are sampled at 2x the prescribed bandwidth, allows for a modified radial PILS reconstruction which reduces aliasing artifacts both from the radial undersampling and the regridding process. Sensitivity maps are first computed using from low resolution images reconstructed using a regridding process that supports 2x the prescribed FOV. The coil sensitivity center is then computed and high resolution images are reconstructed at the coil sensitivity center [2], and multiplied by the coil sensitivity [3]. These images are then shifted back to the prescribed center, summed in the appropriate multi-channel combination, and corrected for variations in the overall sensitivity. PC VIPR images were obtained using a ~9minute acquisition, 75% navigator efficiency, TE/TR=2.8/8.6, VENC=200 cm/s, BW=31.25(62.5)kHz, α=15°, 30x30x20cm FOV, and 0.94mm isotropic resolution. Images were reconstructed use an adaptive temporal filter, with a temporal resolution of 34.4 ms at the center of k-space and 102.2 ms at the edge. Flow measurements in the descending Aorta were then compared to those measured using a typical clinical breath held measurement, with a 20s scan time. Images were also obtained of the renal vasculature, with the sequence modified to VENC=100cm/s and an acquisition time of 4 minutes.

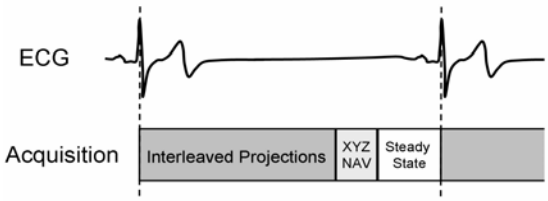

Figure 1. Acquisition timing diagram showing shown positions of interleaved projections, the xyz project set used as a navigator, and steady state recover.

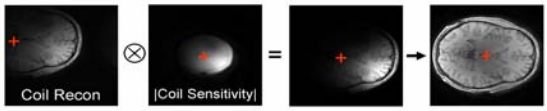

Figure 2. Schematic PILS reconstruction, with the prescribed image center marked.

RESULTS

Representative cardiac images for a single plane and time frame are shown in Figure 3. Anatomical PC VIPR images may viewed as a subtracted (as shown) or magnitude image. Overall image quality is excellent, with little visible artifact from undersampling or respiratory motion. Some signal distortion is observed within the pulmonary system, likely due to off-resonance blurring inherent to the radial sampling pattern. Flow measurements using 2D and 3D PC VIPR are in high agreement, as shown in figure 4. Renal images are shown in figure 5, showing excellent visualization of the renal artieies.

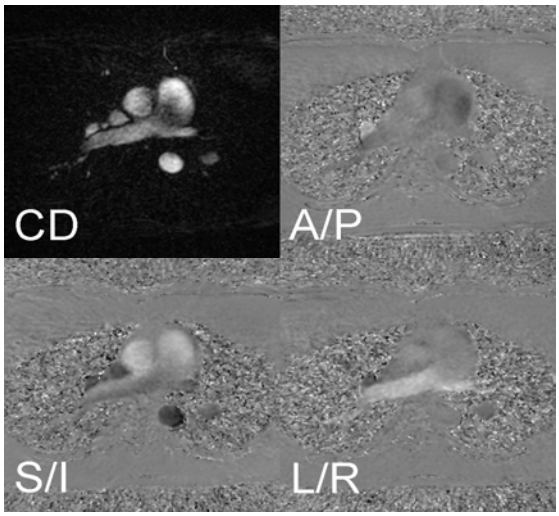

Figure 3.Example axial images from a single slice, showing a complex difference image, and flow in the three directions.

DISCUSSION

3D cardiac flow imaging would be a very powerful tool, if made feasible for routine measurements; especially when combined with advanced visualization [4] and post-processing[5] techniques. PC VIPR is able to provide the temporal and spatial resolution for complex 3D measures including retrospective flow measurements, velocity visualization, and relative pressure measurements. Incremental improvements are expected with the addition of off-resonance corrections currently used for retrospectively gated neurological exams, and the use of a time varying VENC.

REFERENCES

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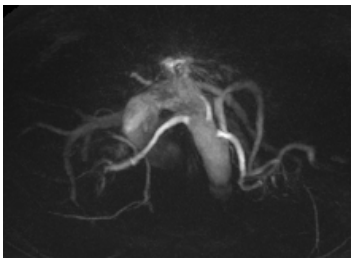

Figure 5. Complex difference axial MIP with excellent visualization of the renal arteries.

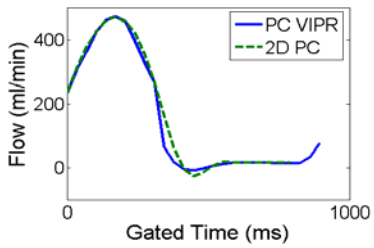

Figure 4. Flow measurements of the descending aorta using PCVIPR(blue) and 2D PC(green)