Volumetric Cine Phase-Contrast MRI of the Great Vessels with PC VIPR: Initial Experience

O. Wieben[1], K. M. Johnson[1], F. R. Korosec[1], C. A. Mistretta[1]
[1]Depts. of Medical Physics and Radiology, University of Wisconsin, Madison, WI, United States

Introduction

Phase contrast MRI provides information on vessel anatomy and quantitative information on flow properties within the vessels. In clinical practice the acquisition is typically reduced to 1D through-plane or 2D in-plane flow encoding for a single slice due to the additional acquisitions required for each flow encoding direction. Here we present initial results for cardiac imaging with PC VIPR, a radial trajectory for ECG-gated 3D flow encoding of a large spherical volume with isotropic spatial resolution to provide information on both vessel geometry and quantitative flow of the great vessels.

Methods

In VIPR (V*astly Undersampled* I*sotropic* PR*ojection Imaging*) acquisitions [1], every readout passes through the center of k-space and the endpoints of the projections are aligned so that their endpoints lie evenly distributed on the surface of a sphere. With VIPR, data are acquired angularly undersampled and provide isotropic resolution over a spherical volume. In some applications with high SNR, such as contrast-enhanced MR Angiography (CE-MRA) and phase-contrast imaging, the reduction in SNR and streak artifacts or pseudo noise from objects of high signal intensity are tolerable. VIPR is particularly well suited for phase contrast imaging as the signal from static tissues is suppressed by subtraction and, therefore, the signal distribution in the data set is very sparse. PC VIPR has been evaluated with flow phantoms and in cranial imaging for average (non-cardiac-gated) flow measurements [2]. Capabilities for cine imaging were added to the sequence, particularly for pressure mapping [3]. More recently, a balanced velocity encoding scheme [4] was used to reduce the minimum TE and TR. In addition, a novel view ordering and temporal filter design was implemented for this study to allow for retrospective ECG gating. The views are ordered such that the endpoints of the projections traverse once from the equator to the pole in order to minimize eddy current effects from jumps in k-space. The projections are retrospectively ordered within the RR interval and the use of a temporal filter as suggested for contrast-enhanced MRA [5] was adopted for the cardiac cycle. The scheme is visualized in Fig. 2: Each image set in the cardiac cycle is reconstructed from projection data of that segment and also shares high spatial frequency information from adjacent cardiac segments for the reduction of streak artifacts. Data were acquired on a 1.5T clinical scanner (Excite HD, GE Healthcare, Waukesha, WI) with the following imaging parameters: FOV = 40-48 cm, Nreadout = 288, flip angle = 20 deg, receiver bandwidth = ±32 kHz, TR/TE = 10/3.5 ms, temporal resolution = 40 ms, venc = 150 cm/s, number of projections = 15,000 (60,000 acquired echoes for 3D flow encoding), total scan time = 10:05 min:sec, images acquired post Gd injection.

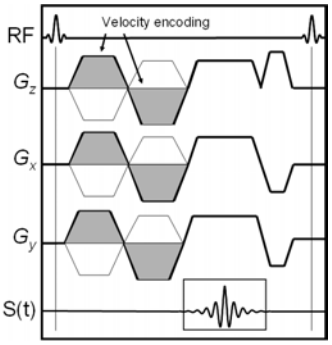

Fig. 1: PC VIPR pulse sequence.

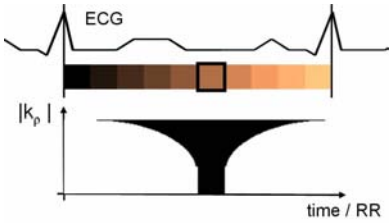

Fig. 2: Temporal filter for cardiac cycle. The projections of the current segment and high spatial frequencies from adjacent segments are combined.

Results

Complex difference maximum intensity projection (MIP) images of representative results are shown in Figure 3. In lean and average weight volunteers, the *in vivo* PC VIPR flow measurements through the pulmonary artery and the aorta were in good agreement with traditional 2D Fourier flow measurements. However, image quality suffered in obese volunteers. For comparison, a MIP image of an ECG gated cranial PC VIPR scan is included in Fig. 3 also.

Conclusion

Our pilot study demonstrates the feasibility and current shortcomings of 4D phase contrast imaging of the great vessels. Data of isotropic resolution and a temporal resolution of 40ms can be acquired over a large FOV in a 10 min exam. This approach might be beneficial in the analysis of complex anatomy where the flow waveforms can be analyzed retrospectively in arbitrary slice orientations after scan completion. For this method, an improved view ordering scheme for retrospective ECG gating and the use of a temporal filter were implemented. While the image quality is excellent in cranial exams, the motion of the chest introduces artifacts which are particularly noticeable in obese subjects. In subjects of average weight, the image quality is improved and the measured flow waveforms correlate well with traditional 2D PC flow measurements. In future work we will investigate the suppression of artifacts arising from off-resonances and the chest wall and explore the inherent motion detection and correction abilities of radial acquisitions to also image and analyze the vessels that move during breathing. At this point, the image analysis is limited to regions that move only minimally during breathing. However, this could be addressed with navigator gating or motion detection and correction from the the information in the radial projections.

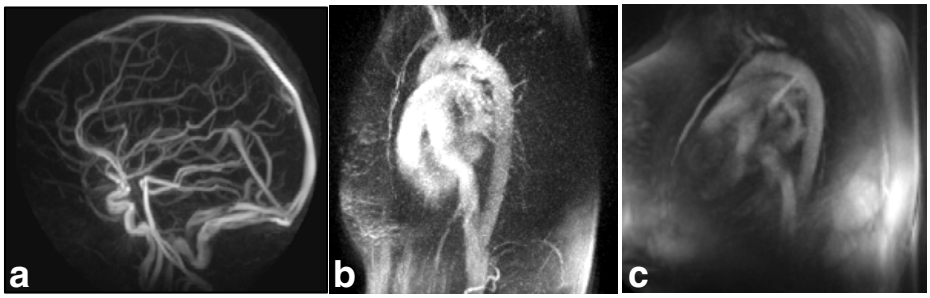

Fig. 3: PC VIPR Complex Difference sagittal MIP images of the head (a), and the great vessels in an average sized volunteer (b), and an obese volunteer (c).

References

[1] Barger AV *et al., MRM*, 44:821-4, 2000.
[2] Gu TL *et al., AJNR,* 26(4): 743-9, 2005.
[3] Johnson KM *et al., 13th ISMRM,* 598, 2005.
[4] Pelc N *et al., JMRI,* 1(4): 405-13, 1991.
[5] Liu J et al., *13th ISMRM,* 1067, 2004.