

PC VIPR for Comprehensive Cardiovascular Evaluation in Congenital Heart Disease

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Introduction Imaging of congenital heart disease usually requires multiple anatomical and functional scans followed by several 2D phase contrast (PC) acquisitions in a variety of oblique scan planes for flow measurements. A new PC acquisition technique has been developed using vastly undersampled isotropic projection reconstruction (PC VIPR) [1], which allows for volumetric 3D CINE flow imaging with high spatial and temporal resolution over a large field of view in a reasonable scan time. The applicability of this approach has been extended to thoracic MRA by implementing a respiratory gating scheme that allows for free breathing acquisition [2]. The high spatial resolution with isotropic voxels improves image quality compared to standard 2D PC by minimizing intravoxel dephasing effects and allows for retrospective data reformatting including flow measurements in arbitrary planes. The objective of this study was to investigate the feasibility of PC VIPR for comprehensive cardiovascular imaging in congenital heart disease.

Materials and Methods PC VIPR data were acquired on 1.5T and 3T clinical systems (GE Healthcare, Waukesha, WI) after obtaining patient consent according to our IRB protocol in a total of 20 consecutive CHD patients with a variety of pathology including aortic coarctation, Scimitar syndrome, double inlet left ventricle, and atrial septal defects, among others. Typical scan parameters were: imaging volume = 320 x 320 x 180 mm³, readout = 256-320, (1.0-1.25 mm)³ acquired isotropic spatial resolution, VENC of 50-150 cm/s (application specific), TR/TE = 8.7/2.8, flip = 10°. Cardiac gating was performed retrospectively with a temporal filter for radial acquisitions, similar to view sharing in Fourier sampling [3]. Respiratory gating was implemented with an adaptive gating scheme based on bellows readings, resulting in a scan time of approx 10 min with 50% respiratory gating efficiency [4]. To reliably achieve high quality images, several correction schemes were applied to account for the effects of T1-saturation, trajectory errors, motion, and aliasing associated with undersampling. The PC VIPR data were reconstructed as magnitude images, velocity vector fields, and angiograms calculated similar to complex difference images. CE-MRA were used for comparisons when available.

Results PC VIPR data sets were successfully acquired in all patients. MR angiograms were created using the magnitude and average flow PC VIPR data in order to visualize cardiovascular structures and to define the vessel boundaries for the derivations of additional hemodynamic parameters. All anatomical structures visualized on CEMRA images were identified on PCVIPR images. This includes a 2 year-old with pulmonary venolobar (Scimitar) syndrome with an anomalous pulmonary venous return to the SVC and IVC, in addition to an anomalous systemic artery. The cardiac gated data were used for advanced hemodynamic analysis. For example, interactive flow measurements were performed in reformatted planes aligned perpendicular to the vessel orientation using advanced software (Ensight, CEI, Apex, NC – see Fig 1b). Fig. 2 shows the hemodynamic analysis for an 18 month old boy with an aortic coarctation. The velocity fields (Fig. 2a) and pressure difference map (Fig. 2b) show changes over the vessel narrowing using the same visualization software. The pressure difference as measured over the coarctation was found to be 12 mmHg (Fig. 2c) and the velocity differences are plotted in Fig 2d. These measurements indicate a mild coarctation as was concluded from the anatomical assessment.

Conclusions Comprehensive anatomical and functional cardiovascular MRI of congenital heart disease can be performed using PC VIPR, providing a powerful new tool for noninvasive diagnosis in congenital heart disease. Future patient studies will investigate the clinical significance of the hemodynamic parameters for various pathologies.

Acknowledgements We gratefully acknowledge funding by NIH grant 2R01HL072260-05A1 and GE Healthcare for their assistance and support.

References [1] TL Gu *et al*, *AJNR* 26(4), 743-9, 2005. [2] KM Johnson *et al*, *Proc ISMRM*, 733, 2008. [3] J Liu *et al*, *IEEE TMI* 25(2), 148-57, 2006. [4] KM Johnson *et al*, *PROC ISMRM*, 733, 2008.

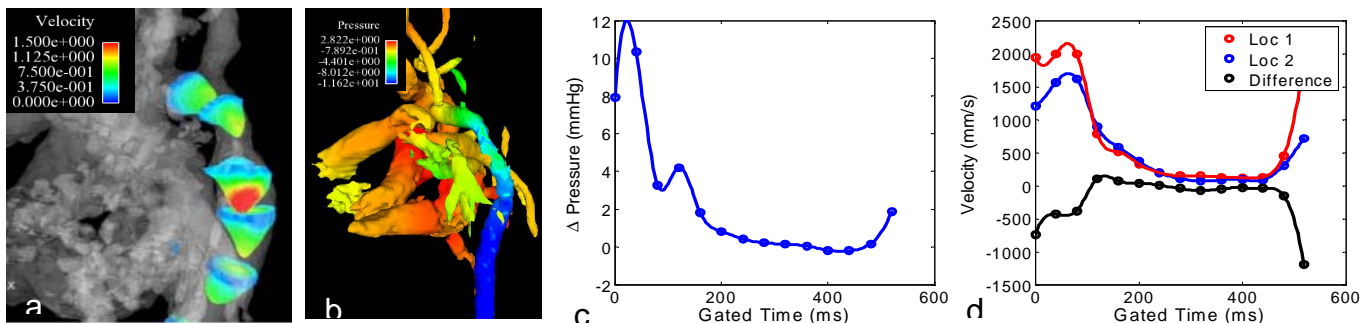


Fig. 2 – Hemodynamic analysis for a patient with aortic coarctation. (a) Flow velocity profiles showing the highest velocity immediately distal to the coarctation. (b) Pressure difference map showing the drop over the coarctation. Pressure difference (c) and velocity (d) measurements over the coarctation as a function of time within the cardiac cycle (peripheral gating).