Intracranial Phase Contrast MRA with Vastly Under-sampled Isotropic Projection Reconstruction (PC-VIPR): Initial Experience at 3.0 Tesla

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INTRODUCTION: At 1.5T, phase-contrast MRA with vastly under-sampled isotropic projection reconstruction (PC-VIPR) of the intracranial vasculature provides isotropic spatial resolution, broader spatial coverage, and smaller voxel sizes than conventional phase contrast three dimensional Cartesian Fourier Transform (PC-3DFT) imaging[1]. Phase contrast imaging is inherently well suited for a radially under-sampled trajectory because of the sparse data set after subtraction of stationary tissues. This allows for high under-sampling factors to achieve large volumetric coverage with 3D velocity encoding in a reasonable scan time; while maintaining high spatial resolution. The data can be processed to demonstrate vessel geometry (complex difference processing) and quantitative flow information (phase difference processing). Here we present our initial results on the imaging characteristics and performance of PC-VIPR at 3.0T. Specifically, we compare the contrast to noise ratios (CNR) of various intracranial vessel beds obtained from PC-VIPR exams acquired at 1.5T and 3.0T. In addition, we assess the image quality of PC-VIPR versus 3D Time-of-Flight (3DTOF) MRA at 3.0T.

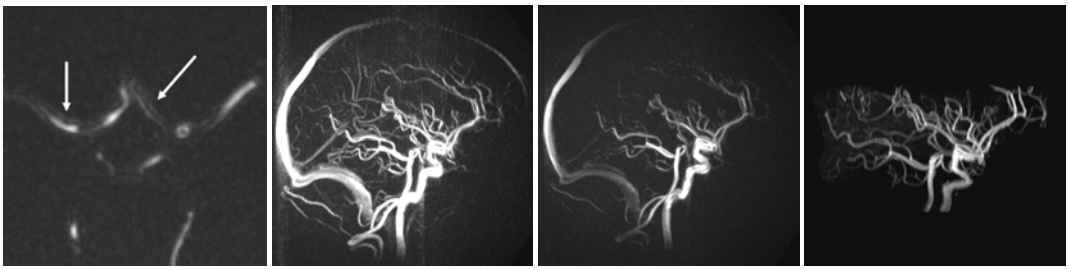
MATERIALS AND METHODS: With institutional review board approval, 2 volunteer subjects (2 women, ages 44 and 50) were imaged on a 1.5-T system (Signa EXCITE HD TwinSpeed; v12; GE Healthcare, Waukesha, WI), and a 3.0-T system (Signa EXCITE HD TwinSpeed; v12; GE Healthcare, Waukesha, WI) after providing written informed consent. PC-VIPR (venc=25cm/s), PC-VIPR (venc=80 cm/s), and 3DTOF intracranial MRA exams were acquired at both field strengths. An acceleration factor of PC-VIPR over 3DTOF was calculated as the product of the ratios of voxel volume, imaging volume, and scan duration. For PC-VIPR, axial complex difference "speed" images were reconstructed. The mean signal intensity (SI) was measured within the vessel lumen and within a paravascular region of interest (ROI) directly adjacent to the vessel using an image analysis workstation (Advantage Windows, v4.2, GE Healthcare, Waukesha, WI). CNR was calculated as the difference between the vessel and paravascular mean SI divided by the standard deviation of a ROI outside of the subject. This was performed at the internal carotid (ICA), basilar (BA), vertebral (VA), middle cerebral (MCA), anterior cerebral (ACA), posterior cerebral (PCA), and posterior communicating arteries (PComA). The mean CNR was compared using a paired t-Test. A single reader qualitatively assessed the axial source and targeted MIP images of both PC-VIPR and 3DTOF with regards to the delineation of distal vessels.

Table 1: Pulse Sequence Parameters

	PC-VIPR	PC-VIPR	PC-VIPR	PC-VIPR	3D-TOF
Field Strength (Tesla)	1.5	1.5	3.0	3.0	3.0
TR (msec)	17.6	17.1	15.2	14.8	22
TE (msec)	6.5	6.0	6.5	6.0	2.2
Flip Angle (degrees)	15	15	15	15	15
Bandwidth (kHz)	15.6	15.6	15.6	15.6	31.2
venc (cm/s)	25	80	25	80	n/a
Field of View (cm)	26	26	26	26	22x16.5
Matrix Size	384x384	384x384	384x384	384x384	320x224
Number of Slices	384	384	384	384	71
Slice Thickness (mm)	0.677	0.677	0.677	0.677	1.8(0.9ov)
z-Axis Coverage (cm)	16	16	16	16	6.4
Voxel Volume(mm^3)	0.310	0.310	0.310	0.310	0.912
Scan Duration (sec)	352	343	305	296	151
Num. of Projections	5000	5000	5000	5000	n/a

RESULTS: An acceleration factor of 4.7 was calculated for PC-VIPR (venc 25cm/s, total scan time 305s) over 3DTOF (total scan time 151s) at 3.0T. CNR was measured at a total of 38 arterial segments. The average CNR (mean +/- STD) of PC-VIPR (venc=80 cm/s) for all arteries was 34.6 +/- 17.7 at 3.0T versus 21.2 +/- 11.7 at 1.5T ($p<0.001$). We observed on average a 190% increase in CNR for all major intracranial arteries at 3.0T. PC-VIPR generated high resolution angiographic images of first order branches of the ACA, MCA and PCA at both field strengths and at both venc settings. The delineation of distal branches of the major intracranial vessels was comparable between PC-VIPR (venc=25cm/s) and 3DTOF at 3.0T. However, distal branch vessels were not as well visualized for PC-VIPR acquired with a higher venc (venc = 80cm/s) at either field strength; likely related to low flow velocities at the distal branches. In addition, vessels were occasionally less well delineated when compared with 3DTOF at 3.0T due to: 1) vessel motion during the cardiac cycle; 2) off resonance effects; and 3) dephasing due to susceptibility at the skull base. Blurring of vessels near the skull base was more severe in PC-VIPR at 3.0T than 1.5T due to increased susceptibility and off-resonance effects.

A: Axial 3.0T PC-VIPR. venc=80 Increased blurring of MCA and ACA near the skull base (arrows); related to off resonance.
B: Sagittal 3.0T PC-VIPR MIP, venc=25 demonstrates better distal branch vessel visualization.
C: Sagittal 3.0T PC-VIPR MIP, venc=80. Note increased coverage with respect to 3DTOF.
D: Sagittal 3.0T 3DTOF MIP.



CONCLUSIONS: In this study, we present our initial experience with PC-VIPR of the intracranial vessels at 3.0T. We demonstrate an incremental increase in CNR for axial complex difference angiographic images at 3.0T versus 1.5T. This increase in CNR at 3T appears to be somewhat offset by the increase in susceptibility and off-resonance artifacts near the skull base. If the venc is appropriately selected, PC-VIPR delineates second order middle cerebral artery branch vessels comparable to 3DTOF. PC-VIPR is a promising technique, capable of producing high resolution angiographic images as well as quantitative flow information over a large imaging volume in a single exam. Further validation and optimization of this technique at 3.0T is currently underway, including application of a dual venc acquisition for optimized velocity-to-noise ratios (VNR) without aliasing and implementation of off-resonance corrections.

REFERENCES:

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