Renal Artery MRA at 3.0T: Initial Clinical Experience with Respiratory-Triggered Non-Contrast-Enhanced Phase Contrast with Vastly Under-sampled Isotropic Projection Reconstruction (PC-VIPR)

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INTRODUCTION: Phase-contrast MRA with vastly under-sampled isotropic projection reconstruction (PC-VIPR) provides isotropic spatial resolution, broader spatial coverage, and smaller voxel sizes than conventional 3D phase contrast imaging with Cartesian sampling.[1] Phase contrast imaging allows for high radial under-sampling factors because of the sparse nature of the image data after subtraction of stationary tissues. Therefore, large volumetric coverage with 3D velocity encoding can be achieved in a reasonable scan time; while maintaining high spatial resolution. The data can be processed to demonstrate vessel morphology (complex difference processing) and quantitative flow information (phase difference processing). Studies validating quantitative trans-stenotic pressure gradient measurements with PC-VIPR were limited at the renal arteries in part due to respiratory motion[2]. Furthermore, initial feasibility studies of vessel morphology with PC-VIPR renal MRA at 1.5T were performed following the administration of intravenous contrast[3]. Given the concern of a possible relationship between gadolinium contrast agents and nephrogenic systemic fibrosis (NSF), we present our initial results on the performance of a respiratory-triggered, non-contrast enhanced abdominal PC-VIPR protocol at 3.0T. The objective of this initial feasibility study is to compare the image quality of PC-VIPR to 3D CE-MRA in volunteers and a series of patients with suspected renovascular disease.

MATERIALS AND METHODS: With institutional review board approval, 4 healthy volunteers and 8 patients (4 women, 4 men, ages 30-72, mean age 55) referred for possible renal artery stenosis provided written informed consent prior to examination. 3 patients had undergone prior renal transplantation. All MR examinations were performed on a 3.0T system (Signa EXCITE HDx TwinSpeed; v14; GE Healthcare, Waukesha, WI). A non-contrast enhanced, respiratory-triggered, dual-echo PC-VIPR[4,5] exam (TR=10.6; TE=3.3; FlipAngle=10°; BW=+/-62.5kHZ; VENC=empirically selected, range 20-100cm/s; FOV=32cm; Matrix=256x256; zero-filled interpolation to 320 slices with 320x320 image dimension; isotropic spatial resolution 1.25mm, interpolated to 1mm; Z-Axis Coverage=12cm; Duration= respiratory gated approx. 10min; 8000 projection angles) was acquired first. Next, a dose of 0.15mmol/kg of gadobenate dimeglumine (MultiHance, Bracco Diagnostics, Inc., Princeton, NJ) was administered for a standard 3D contrast-enhanced MRA (TR=3.4; TE=1.1 (fractional readout); FlipAngle=25°; BW=+/-83.3kHZ; FOV=34 x 27.2 cm; Matrix=256x180; Number Slices = 200; Slice Thickness=1.5mm; in plane resolution 1.3 x 1.5 mm, Duration= 28sec, 2D-ARC parallel imaging in both phase encoding directions). Axial complex difference "speed" images were generated from the PC-VIPR data. Two board-certified radiologists with expertise in vascular imaging assessed the source images interactively in multiple planes independently and in randomized order on a standard PACS workstation (Horizon RadStation, v11.0, McKesson Medical Imaging Group, Richmond, BC). Image quality was rated on a five-point scale (4 = excellent, 3 = good, 2 = fair, 1 = poor, 0 = non-diagnostic). For renal transplant patients, the vessels assessed included the proximal and segmental transplant renal artery, the infrarenal abdominal aorta, and the bilateral common iliac arteries. For exams of the native renal arteries, the vessels assessed were the abdominal aorta, the celiac trunk, the superior mesenteric artery, the proximal and segmental renal arteries, and the proper hepatic artery and its branches. Scores are reported as medians. In addition, a single radiologist performed measurements of vessel diameter based upon double oblique reformatted images perpendicular to the vessel (Vitrea 2, Vital Images, Minnetonka, MN). For transplant patients, measurements were made at the infrarenal aorta, proximal transplant renal artery, bilateral common, external, and internal iliac arteries. For the native renal exams, measurements were performed at the aorta (just superior to the highest renal artery), the origin of the renal arteries, 1 cm distal to the origin of the renal arteries, the origin of the celiac trunk, the origin of the superior mesenteric artery, and 1 cm distal to the origin of the superior mesenteric artery. Pearson product moment correlation coefficient was calculated and Bland Altman analysis was performed to compare agreement between the two techniques for measurement of vessel diameter.

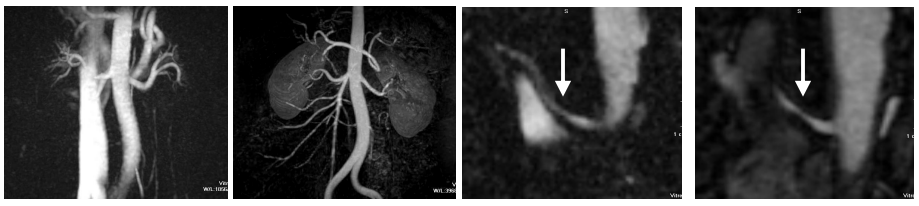
RESULTS: A total of 87 vessel segments were assessed independently by the two readers. A score >= 2 was considered to be diagnostic. Reader 1 rated 75/87 (86%) of segments to be diagnostic for PC-VIPR and 80/87 (92%) segments diagnostic for CE-MRA. Meanwhile, Reader 2 rated 83/87 (92%, PC-VIPR) and 85/87 (98%, CE-MRA) of the evaluated segments diagnostic. A score of 3 or 4 (good or excellent) was assigned to the segmental renal arteries in 16 (76%, Reader 1) and 17 (81%, Reader 2) of 21 PC-VIPR; versus 11 (52%, Reader 1) and 14 (67%, Reader 2) of 21 CE-MRA exams.

Table 1: Median Image Quality Scores

	Reader 1 PC-VIPR	Reader 1 CE-MRA	Reader 1 PC-VIPR	Reader 2 CE-MRA
Total	4	3	3	4
Proximal Renal Artery	4	4	4	4
Segmental Renal Artery	4	3	3	3

Measurements of vessel diameter could not be performed at the iliac arteries for two of the transplant patients due to non-visualization of these vessel segments. The poor visualization of these vessels was secondary to slow flow with subsequent spin saturation in the imaging volume. A total of 95 paired double oblique vessel diameter measurements were performed. The vessel diameters (PCVIPR (mean+/-STD): 9.3mm+/- 4.9, range 2 – 21.7mm; CE-MRA (mean+/-STD): 9.3mm +/- 5.0, range 2 – 20.6mm) correlated highly (r=0.989, p<0.0001). Bland Altman plots showed good agreement between the two techniques (bias = -0.06mm; limits of agreement -1.58mm to 1.45mm).

A: Coronal PC-VIPR MIP
B: Coronal CE-MRA MIP. Renal parenchymal enhancement obscures visualization of the segmental renal arteries.
C: Oblique sub-volume PC-VIPR MIP of right renal artery stenosis
D: Oblique sub-volume CE-MRA MIP of right renal artery stenosis



CONCLUSIONS: In this study, we present our initial clinical experience with respiratory-triggered, non-contrast enhanced PC-VIPR MRA of the abdominal vessels at 3.0T. We demonstrate comparable image quality between PC-VIPR and CE-MRA. Furthermore, PC-VIPR provides improved conspicuity of the segmental renal arteries due to the subtraction of stationary background tissues. Finally, we find good agreement between the two techniques for measurements of vessel diameter. In patients who cannot receive contrast secondary to the risk of NSF, PC-VIPR may be an alternative to abdominal CE-MRA. In addition, respiratory-triggered, non-contrast enhanced PC-VIPR MRA may also serve as a useful adjunct to CE-MRA for visualization of the distal segmental renal arteries. Further validation and optimization of this technique at 3.0T is currently underway.

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