4D PC MR of the portal venous system: Benefits of using a Blood Pool Contrast Agent

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Introduction Advances in hardware and accelerated acquisition schemes have facilitated increasing use of 4D flow imaging for the simultaneous assessment of vascular anatomy and CINE velocity fields in clinically feasible scan times. Recent studies with Cartesian [1] and radial [2] 4D PC MR sequences have shown improved signal characteristics from intravascular contrast agents when imaging the chest and renal vasculature. These studies showed improved SNR in the magnitude data, decreased noise in the velocity measurements, and improved vessel conspicuity in the derived angiograms and streamline visualizations for all vessels except for segmental branches of the renal arteries due to the enhancement of renal parenchyma. The purpose of this study is to compare radially encoded flow sensitive MR data in the portal venous system acquired before and after the injection of an intravascular (high Albumin binding) contrast agent.

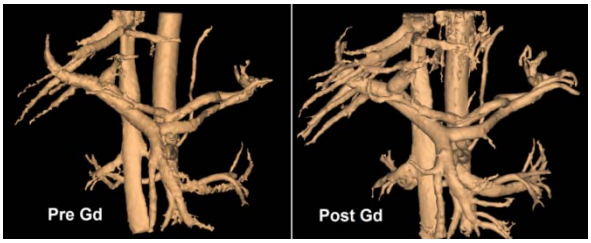

Fig. 1 Surface rendered hepatic angiograms before and after injection of an intravascular contrast agent.

Materials and Methods Four volunteers (33.5±10.6 years, 84.5±9.7kg, 3M, 1F) were imaged on a clinical 3T system (Discovery MR750, GE Healthcare, Waukesha, WI) after obtaining IRB approval and written informed consent from all subjects. PC VIPR images of the upper abdomen were acquired before and after the administration of of the recently FDA-approved blood pool agent gadofosveset trisodium (Ablavar, Lantheus, Billerica, MA) (0.03mmol/kg at 0.6ml/s). Typical scan parameters included: dual echo PC VIPR sequence [3], imaging volume = 320x320x220 mm^3, $(1.25\ mm)^3$ true isotropic spatial resolution, VENC =100 cm/s, TR/TE=6.4/2.2ms (first echo), intravenous injection of 0.03mmol/kg of gadofosveset trisodium (Ablavar, Lantheus, Billerica, MA), retrospective ECG gating, adaptive respiratory gating with 50% acceptance window, scan time: ~ 10-12 min. In contrast to previous reports, flip angles were chosen based on the Ernst angle of blood without (6^o) and with (15^o) contrast to maximize SNR performance. PC VIPR data were reconstructed as time averaged magnitude images and angiograms calculated similar to complex difference images [4] (see Fig. 1).
Assessment of ***PC angiogram image quality*** was performed in a consensus reading by two radiologists. Image grading was performed on a 0-4 scale (1=non-diagnostic; 1=fair, some diagnostic value; 2=good; 3=very good; 4=outstanding image quality). Further, the **generation of detectable portal branches** was recorded. To obtain quantitative image quality parameters, **relative contrast-to-noise measurements (CNR)** were calculated on magnitude images. ROIs were drawn in the aorta (AO) and portal vein (PV) of the enhanced image and copied to the unenhanced image. Similarly, a ROI was drawn in liver tissue free of large vessels and paraspinal muscle, both as reference tissue. Relative CNR was calculated as CNR = (SI_reference - SI_vessel)/SI_reference with signal intensity measurements from the ROIs.
To evaluate the ***effect on visualization quality***, the time-resolved velocity maps were processed using a dedicated software package for dynamic vector fields (EnSight, CEI, Apex, NC). Color-coded 3D streamlines w ere emitted from planes placed within the splenic vein and superior mesenteric vein (see Fig. 2). The density of the emitters was held constant, ie, the number of emitters released was proportional to the cross-sectional area of the vessels. Analysis was based on the distance traveled by the streamlines, and the vessel branching generation in which streamlines persisted.

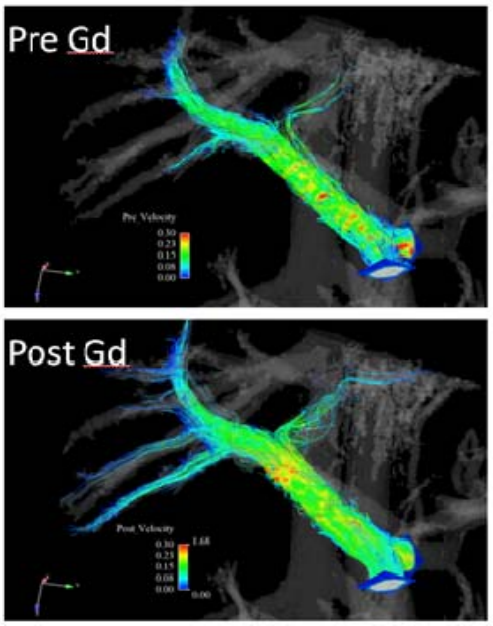

Fig. 2 Streamline visualization (peak systole) flow patterns of the same subject acquire pre and post contrast injection.

Statistical analysis was performed using a paired, two-sided student's t-test ($p<0.05$ was considered significant).

Results Representative PC angiograms for the portal venous system acquired with and without a blood pool agent are shown in Fig.1, demonstrating subjective improvement in the visualization of the portal vein. The radiologist's grading results demonstrated very good image quality in all pre-contrast studies and outstanding image quality in all post-contrast studies (Fig 3A). Also, a median of 3 branch generations was identified on pre-contrast angiograms, whereas a median of 4 branch generations were identified on post contrast angiograms (Fig. 3A). CNR measurements are summarized in Fig. 3B and demonstrate significantly improved relative CNR performance for post-contrast imaging. Visualization of velocity fields was improved in each of the post Gd scans as compared to non- contrast-enhanced exams. The right and left portal vein was successfully visualized in all data sets and the level of branching seen by the streamlines is summarized in Fig. 3C

A **Angiography grading**

	Pre Contrast	Post Contrast
Order of PV branches visible	2.75±0.5	3.75±0.5
CD image grading	2.75±0.5	4.0±0

B **CNR comparison**

PV vs. liver	0.52 ± 0.10	0.84 ± 0.12
PV vs. muscle	0.40 ± 0.13	0.81 ± 0.20
AO vs. liver	0.58 ± 0.11	0.72 ± 0.15
AO vs. muscle	0.40 ± 0.04	0.71 ± 0.12

All differences revealed statistically significance ($p<0.05$)

C **Visualization comparison**

Left and right PV was visible in every data set

Branches of left PV	0.75 ± 0.95	1.75 ± 0.95
Branches of right PV	5.00 ± 1.82	8.00 ± 0.82

Fig. 3 Results of statistical analysis.

Conclusions This study demonstrates good image quality in PC VIPR imaging of the portal venous system with and without an intravascular contrast agent. This approach is suitable for generating angiograms and providing volumetric velocity maps without the use of contrast material. Therefore, it can be used as a non-contrast-enhanced MRA technique with the added benefit of hemodynamic information. When imaging after the injection of a contrast agent, vessel signal and contrast are increased, resulting in higher quality angiograms and improved VNR in the velocity maps and higher quality hemodynamic visualizations. Contrary to renal 4D PC MRI where conspicuity of segmental renal arteries can be reduced, the use of a contrast agent in the portal venous system showed only benefits and no disadvantages.

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References[1]J. Bock et al, MRM 2010:63(2):330-8.[2] M. Loecher et al., Proc ISMRM 2010, 1390.[3] K. Johnson et al., MRM 2008:60(6):1329.[4] A. Anderson et al., Proc ISMRM 2008, 934.