

Hemodynamics of Portal Hypertension with 4D Radial Phase Contrast Imaging: Feasibility at 3.0T

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Introduction: Portal hypertension (PHTN) is a complication of cirrhosis associated with significant morbidity, including varices, variceal rupture, ascites, portal venous thrombosis, and encephalopathy. Current non-invasive evaluation of PHTN is confined to angiographic assessments with MRA and CTA and limited hemodynamic assessment with ultrasound. Recent work has described the ease of demonstrating 4D flow characteristics in the portal venous system to obtain anatomical and quantitative information [1]. The purpose of this study is to demonstrate the feasibility of 3D radial phase contrast imaging for high-resolution comprehensive evaluation of the hemodynamics of PHTN using a 32-channel phased array coil at 3.0T. Comprehensive PC imaging in the liver is challenging due to the markedly different velocities in the hepatic artery and tributaries of the portal vein, which can change dramatically with disease. To image a wide range of velocities without velocity aliasing or increased noise, a highly efficient 5-point velocity encoding strategy was employed [2].

Methods: After obtaining informed consent according to this IRB-approved study, MRI studies were performed in two normal volunteers (2 males, both age 23) and in five patients (M=2, ages 58-66; F=2, ages 23-57) with known cirrhosis and PHTN was performed. All imaging was performed on a 3.0T clinical scanner (MR750 v20.0, GE Healthcare, Waukesha, WI) using a 32-channel phased array body coil (Neocoil, Pewaukee, WI). Images were acquired using a 3D radially undersampled PC sequence (PC-VIPR) as previously described [3], using respiratory gating [4] and retrospective cardiac gating. Specific image parameters included: FOV=32cm, BW=125 kHz, with 24,000 total projections, for true isotropic spatial resolution of $1.3 \times 1.3 \times 1.3\text{mm}^3$, temporal resolution of 74ms, VENC=60cm/s, and total scan time on the order of 10 minutes. 20 interpolated time frames were reconstructed with an automated offline reconstruction algorithm. Angiographic images derived from the PC images were segmented using Mimics (Materialise, Ann Arbor, MI), and analyzed using commercially available analysis and visualization software (Ensight 9.0 CEI, Apex, NC).

Results: Excellent image quality was achieved in all volunteers and patients. Flow was demonstrated in both the hepatic arteries and portal veins. Examples are shown in figures 1-4 using different segmentation and velocity visualization approaches.

Figure 1 demonstrates a pattern of right-handed helical flow in the portal vein of a volunteer. Particle tracings used blue seed points in the splenic vein and red points in the superior mesenteric vein (SMV) to demonstrate the helicity of this laminar flow.

Figure 2 shows images from a 58 yo male cirrhotic with cryptogenic cirrhosis demonstrating normal flow direction in the portal vein and splenic vein (hepatopetal flow), but reversed flow in several small tributaries of the portal vein, including the coronary vein and inferior mesenteric vein.

Figure 3 shows images from a 23 yo woman with a history of biliary atresia, repaired a neonate with a hepaticojunostomy (Kasai procedure), now presenting for liver transplant from end-stage cirrhosis from chronic biliary stasis. Complete reversal of flow in the portal vein and splenic vein (hepatofugal flow) was seen, along with reversed venous through massive spleno-renal varices.

Figure 4 shows a 66 yo male with end-stage cirrhosis, and two recanalized paraumbilical varices draining the left portal vein in a parallel manner, which had hepatopetal flow. Stream-line visualization shows an unusual configuration of these parallel paraumbilical veins that had a narrow connection superiorly. The hepatic artery is also well visualized (red).

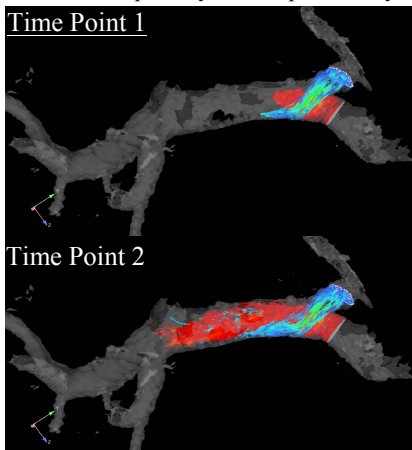


Figure 1: Right handed helical laminar flow is demonstrated in the portal vein of a normal volunteer after the confluence of the splenic vein (blue) and superior mesenteric vein (SMV). Two time points demonstrate the progression of flow in the portal vein.

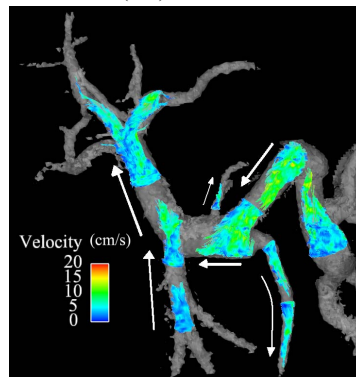


Figure 2: Hepatopetal flow in the portal, superior mesenteric, and splenic veins in this patient with cirrhosis. However, reversed flow is seen multiple tributaries, including the coronary and inferior mesenteric veins, demonstrating how 4D-PC methods provide more comprehensive evaluation of PHTN.

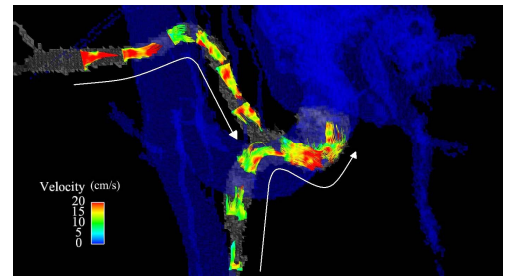


Figure 3: Reversed flow (hepatofugal) flow is demonstrated in the portal vein and SMV of a 23 year old patient with biliary atresia status post Kasai procedure, now with end-stage liver disease. Massive spleno-renal venous collaterals also demonstrate flow into the left renal vein and IVC (flow traces not shown).

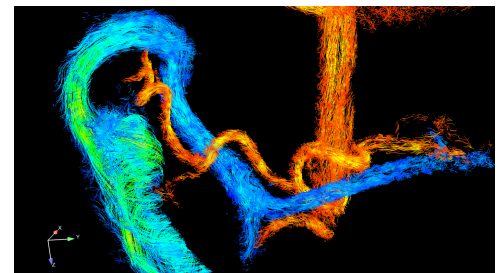


Figure 4: Streamline visualization in a patient with PHTN and a large, complex recanalized paraumbilical vein that shunts blood from the liver. Flow in the portal vein, splenic vein and SMV has normal direction, but most portal venous flow drains through the left portal vein into the large shunt. Excellent visualization of the celiac axis and hepatic artery is also noted.

Discussion: This work demonstrates the feasibility of 4D-PC velocity imaging in patients with PHTN at 3.0T using a 32-channel phased array coil. Comprehensive evaluation of the portal venous system and hepatic arteries offers tremendous potential for definitive, non-invasive evaluation of flow to the liver. This offers new opportunities for non-invasive evaluation of the hemodynamics of PHTN with implications for prognosis, treatment and early detection of disease.

References: [1] Stankovic ISMRM 2009, [2] Johnson MRM 2009, in press, [3] Gu AJNR 2005; [4] Johnson ISMRM 08 # 733

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