**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. Images were acquired using a 3D radially undersampled PC sequence (PC-VIPR) as previously described [3], using respiratory gating [4] and prospective cardiac gating. Specific image parameters included: FOV=32cm, BW=125 kHz, with 24,000 total projections, for true isotropic spatial resolution of 1.3 x 1.3 x 1.3 mm³, temporal resolution of 74ms, VENC=60 cm/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 hepaticojejunostomy (Kasai procedure), now with end-stage liver disease. Massive spleno-renal varices also demonstrate flow into the left renal vein and IVC (flow traces not shown).

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).

**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.


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