# Volumetric Phase Contrast Imaging of the Hepatic Vasculature

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**Target Audience:** Interventional Radiologists, Body Imagers, and MR physicists involved in protocol development and sequence optimization for the pre/post procedure evaluation of portal hypertension.

**Backround/Purpose**: Portal hypertension is a manifestation of end-stage liver disease and patients often present with recurrent symptoms such as ascites, variceal bleeding, and hepatic hydrothorax (1). Portal hypertension results in complex flow dynamics with development of enlarged vessels (varices) and variable collateral pathways for flow (such as splenorenal or mesocaval shunts). Treatments for portal hypertension, such as transvenous intrahepatic portosystemic shunt (TIPS) and balloon-occluded retrograde transvenous obliteration (BRTO), are aimed at reducing the morbidity by reducing the portosystemic gradient and/or treating varices, but may have variable success depending on the flow dynamics in the portal venous system (2-3). The gold standard in evaluating portal hypertension severity is the portosystemic gradient, which is obtained indirectly and requires an invasive procedure. The portosystemic gradient may be artificially low or unreliable in some patients with large shunts. Multi-directional phase contrast imaging has been successfully performed in normal patients and in patients with portal hypertension (4-6) and we proposed it has the potential to qualitatively and quantitatively assess the complex flow dynamics in the setting of portal hypertension prior to and after an intervention.

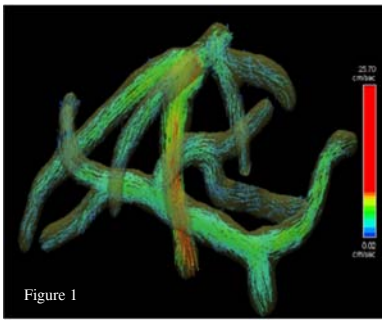
Figure 1

**METHODS:** Following IRB approval at our institution, normal patients, patients with portal hypertension, and patients status post TIPS were selected to undergo MR examination which included balanced steady state free precession (True FISP) sequence for anatomic imaging and free –breathing volumetric phase contrast imaging (with ECG and navigator echo gating) for hepatic vasculature flow quantification. The examinations were acquired on a 1.5T MAGNETOM Avanto (Siemens Healthcare, Erlangen, Germany) with Total Imaging Matrix six element body coil and six to nine elements of the spine matrix coil. For the free breathing 4D flow sequence, a 90°-180° navigator echo was placed at the spleen/lung interface to track the diaphragm movement. A navigator acceptance window of 6-10 mm (+/- 3-5 mm) was used for gating. The 3D phase contrast slab was placed transversely with venc = 50 cm/sec in all three directions, with the following imaging parameters: number of segments = 3, phases = 10, slices per slab = 30, FOV = 380 mm, phase FOV = 56%, base resolution = 160, TE= 3.73 msec, TR= 81.72 msec, thickness = 3 mm, Flip angle = 8°, bandwidth = 488 Hz/pixel. iPAT acceleration factor of 2 with 24 reference lines was used. Acquisition time ranged from 12-20 minutes. Post--processing and visualization were performed using Siemens 4D flow post-processing research prototype (Siemens Healthcare, Erlangen, Germany). Images were post processed to segment and analyze the portal and hepatic vein system with the resultant quantitative values compared to previously described normal patients, Doppler ultrasound measurements, and invasive portosystemic gradient values.

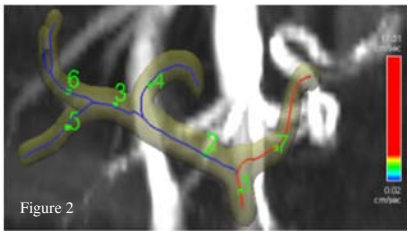

Figure 2

**RESULTS**: Segmentation and quantitative analysis was successful for the portal venous system and the hepatic veins (Figure 1) in normal patients (NL) and patients with portal hypertension (PHTN) using a velocity encoded value of 50 in x, y, and z directions. Quantitative values (*i.e.* flow rate-net, forward, and reverse; velocity-peak and mean) were obtained in the portal venous system and its major branches (Figure 2) in normal patients and patients with portal hypertension. MPV peak velocity (NL 16.3 cm/s; PHTN 14.4-16.0 cm/s). Segmentation and quantitative analysis was successful in the main portal vein, the right portal vein, all portions of the TIPS and the IVC in a patient with pre-existing TIPS (Figure 3) using a velocity encoded value of 250 in all directions. The TIPS graft was patent with velocities of 158 cm/s proximal, 180 cm/s mid, and 108 cm/s distal. A range of values were obtained in each position with Doppler Ultrasound examination performed immediately prior to 4D flow, with the single velocity used for interpretation in bold (Table 1).

**DISCUSSION:** Qualitative and quantitative noninvasive non contrast evaluation of the hepatic veins and portal veins is feasible with a free-breathing ECG gated non-contrast technique. We successfully imaged normal patients, patients with portal hypertension and patients after placement of TIPS with internally consistent quantitative values corroborated with invasive wedge and free hepatic vein pressures and Doppler ultrasound.

| Table 1 | MPV | RPV | Proximal | Mid | Distal |
|---|---|---|---|---|---|
| **Ultrasound** | **36** cm/s | **37** cm/s | 173-222; **184** cm/s | 169 - **175** cm/s | **125** – 135 cm/s |
| **4D Flow** | 30cm/s | 37cm/s | 158cm/s | 180 cm/s | 108cm/s |

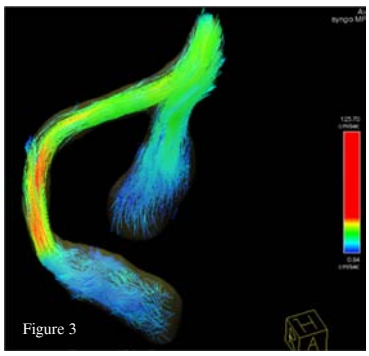
Figure 3

**CONCLUSION:** Volumetric phase contrast MRI may provide reproducible user-independent velocity and flow quantification information in a patients with portal hypertension assisting in both pre-procedure planning and post-procedure follow-up.

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