Quantification of Hepatic Blood Flow in Portal Hypertension using 4D-flow MRI: a Meal Challenge Study

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Target audience: Those with an interest in cirrhosis, portal hypertension and hemodynamic changes in the mesenteric and hepatic circulation.

Introduction: Portal hypertension is an end-stage complication of cirrhosis that leads to dramatic and complex alterations in the hemodynamics of the liver and the mesenteric circulation. Currently, there are few valid quantitative biomarkers to assess blood flow to and from the liver. Phase contrast 4D-flow MRI methods hold great promise to overcome the challenges associated with comprehensive non-invasive flow measurements in the abdomen [1,2,3]. ***The purpose of this study*** was to quantify changes in hepatic and mesenteric flow in patients with portal hypertension undergoing a meal challenge, which can lead to characteristic flow [4].

Methods: In this IRB-approved and HIPAA-compliant study, 8 patients (51.6±13.8years, 75.7±23.5kg) with portal hypertension, evidenced by the presence of varices and splenomegaly, were imaged after written informed consent was obtained.

Meal challenge: The first MR scan (pre) was performed after at least 5 hours of fasting. After this, subjects ingested 574mL EnSure Plus® (Abbot Laboratories, Columbus, OH; 700cal, 28% from fat, 57% from carbohydrates) orally. A second acquisition (post) was started 20min after the meal challenge.

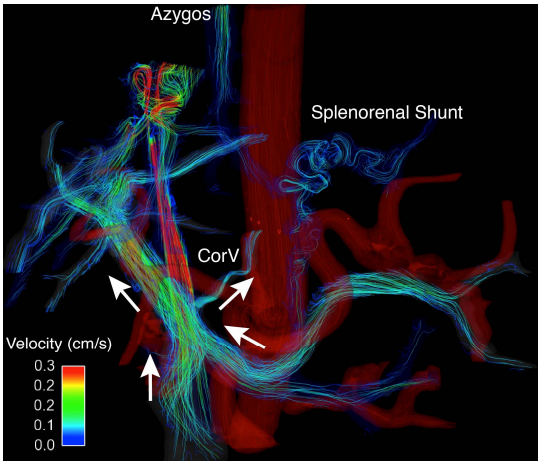

Figure 1– 4D Flow visualization post meal in a patient with portal hypertension. Retrograde flow (white arrows) through the coronary vein (CorV). Increased blood flow through the azygos as well as the presence of a splenorenal shunt.

MR-Imaging. Studies were conducted on a clinical 3T scanner (Discovery MR 750, GE Healthcare, Waukesha, WI) with a 32-chanel body coil (NeoCoil, Pewaukee, WI). 4D velocity mapping was achieved using a radially undersampled phase contrast acquisition (5-point PC-VIPR) with increased velocity sensitivity performance [5,6] and comprehensive coverage of the upper abdomen. Radial 4D flow MRI image parameters included: imaging volume: 32x32x24cm spherical, 1.25mm acquired isotropic spatial resolution, TR/TE=6.4/2.2ms. All subjects received 0.03mmol/kg of gadofosveset trisodium (Lantheus, N. Billerica, MA), an intravascular gadolinium based contrast agent used to maximize SNR performance and injected prior to the pre-meal scan. Pre- and post meal challenge PC-VIPR imaging was adjusted for optimal imaging conditions and differed in the venc: (pre=100cm/s, post=120cm/s) and flip angle (pre=16°, post=14°).

4D flow MRI Data Analysis: *V*essel segmentation was performed in MIMICs (Materialize, Leuven, Belgium) from PC angiograms and manual placement of cut-planes in the vessel of interest after importing the segmented masks into EnSight (CEI, Apex, NC) were flow measurements and visualizations were conducted.

Statistics: Flow data were acquired at the supraceliac Aorta (Ao), Azygos vein (Azy), Hepatic Artery (HA), Portal Vein (PV), Superior Mesenteric Artery (SMA), Superior Mesenteric Vein (SMV), Splenic Vein (SV), and Celiac Trunk (CT). Flow values measured in each vessel were compared before and after the meal challenge using paired Student t-tests. A p-value of 0.05 was chosen to indicate statistical significance.

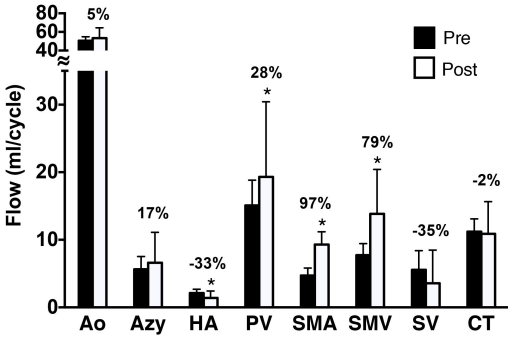

Figure 2 – Blood Flow changes induced by the meal challenge. Flow measurements were done at the supraceliac Aorta (Ao), Azygos vein (Azy), Hepatic Artery (HA), Portal Vein (PV), Superior Mesenteric Artery (SMA), Superior Mesenteric Vein (SMV), Splenic Vein (SV), Celiac Trunk (CT). *statistical significance p<0.05.

Results and Discussion: Segmentation quality of the hepatic and splanchnic angiograms demonstrated excellent vascular detail in all cases (eg. Fig.1). Statistically significant increases in blood flow were seen in the PV, SMV and SMA. As expected, decreased flow was seen in the HA and SV, however SV flow decrease was not statistically significant. This decrease in HA blood flow is likely due to the hepatic arterial buffer response (HABR), a weel-described physiological response to increased PV flow. One patients had reversed flow in the splenic vein both pre and post-meal (6.5 and 5.6 ml/cycle, respectively) and very low flow in the portal vein (2.2 and 3.3 ml/cycle, respectively). Another patient (Fig 1) demonstrated elevated blood flow in the azygos vein. The azygos vein is a known venous drainage pathway of collateral venous flow form the liver in portal hypertension and flow in the azygos is known to correlate with variceal bleeding in patients with portal hypertension [7]. This patient also had reversed flow in the coronary vein (CorV) (0.07 and 0.142 ml/cycle pre- and post-meal respectively) and a splenorenal shunt.

Summary: Radial 4D flow MRI can characterize and quantify blood flow in the entire hepatic system with comprehensive coverage and simultaneous acquisition of a high quality angiogram. The ability to non-invasively identify collateral vessels and quantify hemodynamic changes demonstrates that 4D flow MRI may be a suitable tool for staging and monitoring treatment of patients with portal hypertension.

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References: [1] Stankovic JMRI 2010; [2] Frydrychowicz JMRI 2011; [3] Roldán-Alzate JMRI 2012 [4] McCormick J Hepatol 1990 [5] Gu AJNR 2007; [6] Johnson MRM 2010; [7] Bosh J Hepatol 1985