Geometry and Flow in the Portal Vein of Normal Subjects and Patients using Magnetic Resonance Imaging

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Introduction: Cirrhosis is a leading cause of death in the United States. Previous studies have compared portal vein blood flow and velocity in normal subjects and patients with varying results (1-4). In comparing grades of cirrhosis, based on the "Child-Pugh" score, portal flow was significantly affected as the degree of cirrhosis increased (1-3). These previous studies have used a variety of imaging methods; the most common being Doppler Ultrasound (1-4). The use of Magnetic Resonance Imaging (MRI) and phase contrast (PC) –MRI has not been used extensively to study liver hemodynamics. When compared to ultrasound, MRI is often superior in providing anatomical and hemodynamic information. Due to technical limitations of the other imaging methods, there has also been no in depth study of normal portal vein hemodynamics, an important step for understanding changes of cirrhosis. This study evaluates the use of PC-MRI to characterize normal and patient portal venous hemodynamics and preliminarily compare normal and patient blood flow characteristics in a small number of subjects. The long term clinical objective is to develop non-invasive diagnostic methods to evaluate and monitor the progression of cirrhosis in patients with chronic liver disease.

Methods: To date this study includes 6 normal subjects and 4 patients. The normal subjects were selected to participate based on no previous or current diagnosis of liver disease and the patients were selected from those scheduled for an abdominal MRI with a diagnosis of cirrhosis. The scans were completed on either a Philips 1.5T Intera system or Siemans Avanto 1.5T system both equipped with a body phased array coil. The vessel geometry, including the superior mesenteric vein (SMV), splenic vein (SV), complete portal vein (PV), and the right and left portal vein branches (RPV & LPV), was scanned using a steady-state free precession technique (SSFP). The scans were breath-held contiguous slices of 3 mm thickness with a resolution of 1.56x1.56mm. PC-MRI scans were preformed during the same session as the geometry acquisition. ECG leads or a Peripheral Pulse Unit (PPU) was applied for cardiac vector cardiogram gating. Velocity data were gathered from breath-hold cardiac-gated PC-MRI using a segmented gradient echo sequence obtained from the mid-portal vein with the imaging plane placed at 90 degrees to the long axis of the vein. PC-MRI scans were also done for the SMV and SV before the PV confluence and the RPV just after the PV bifurcation. Scan parameters were as follows; slice thickness 6-8mm, resolution >1.17x 1.17mm, TR 24.2, TE 8, number of phases 16-20, and Venc 30-60cm/s. Image registration and segmentation techniques were applied to the data sets. The portal vein and its connected veins were then extracted and visualized in 3D as surfaces. Image post-processing was performed using a MATLAB program segmenting the magnitude portion of the PC-MRI images based on threshold criteria in a region of interest Next, the segmented magnitude images were used as a mask to multiply the velocity images, thus leaving only the velocity information of interest. Then the velocity intensities were converted to actual velocity values using a MATLAB program we developed for this application. The liver was segmented by hand in 3D-Doctor, a commercial program, and the volume, including vessels, was calculated.

Results: An example of a normal subject's geometry is displayed in Figure 1. Of note is the narrowing of the SMV before the PV confluence due to the pancreas. The PV flow showed little velocity and flowrate changes over the cardiac cycle in both subject groups. A sample of PV velocity contours in both a normal subject and patient is seen in Figure 2. The patients (n=4) had a lower average PV velocity and higher average PV flowrate as compared to the normal subjects (n=6). The velocity and flowrate per liver volume were calculated for 5 normals and 4 patients. The patients had a lower velocity/volume ratio and a higher flowrate/volume ratio. However, in both cases it was not possible to establish statistical significance due to the limited number of subjects. These data are summarized in Table 1 and 2.

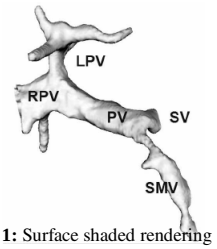

Figure 1: Surface shaded rendering of the PV from SSFP images

Table 1: Portal Vein Parameters

	Normal (n=6)	Patient (n=4)
Average Velocity (cm/s)	12.96 +/-3.44	8.68 +/- 3.15
Average Flowrate (ml/min)	786.28 +/- 263.7	998.8 +/- 602.9
Average Area (cm^3)	0.989 +/- 0.0793	1.73 +/- 0.525

Table 2: Portal Vein Parameters / Liver Volume

	Normal (n=5)	Patient (n=4)
Ave Vel/Liver Volume	0.0101 +/- 0.0024	0.00677 +/- 0.0028
Ave Flowrate/Liver Vol	0.5014 +/- 0.329	0.754 +/- 0.43

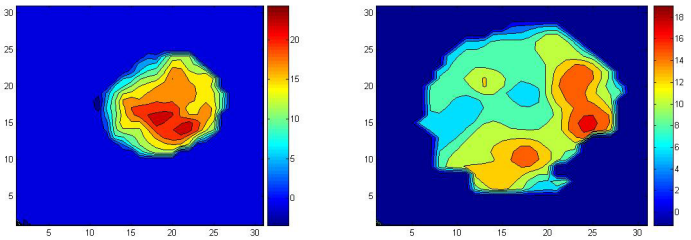

Figure 2: Cross-sections displaying velocity magnitude (cm/s) at maximum velocity in the cardiac cycle; (a) Normal and (b) Patient.

Conclusions: This study demonstrates the feasibility of PC-MRI determination of detailed normal and patient portal vein hemodynamics and preliminarily characterizes flow. Additional subjects must be studied, including patients with varying stages of disease, in order to investigate hemodynamic parameters that can be utilized in clinical and pathological staging of disease. These data also provide boundary conditions for computational fluid dynamics (CFD) to create normal and patient specific models.

References:

1. Kayacetin E *et al, Journal of Gastroenterology,* 2004 2. Kutlu, R *et al, Journal of Clinical Ultrasound,* 2002 3. Vyas K *et al, Indian Journal of Gastroenterology,* 2002 4. Yin, XY *et al, Journal of Clinical Ultrasound,* 2001