Qualitative and Quantitative Evaluation of Time-resolved Flow Analysis of Portal Venous Hemodynamics of Liver Cirrhosis Patients and Volunteers

Z. Stankovic[1], Z. Csatari[1], P. Deibert[2], W. Euringer[1], W. Kreisel[2], S. Eggerking[2], P. Blanke[1], Z. Abdullah Zadeh[1], J. Hennig[1], M. Langer[1], and M. Markl[1]
[1]Department of Diagnostic Radiology and Medical Physics, University Hospital Freiburg, Freiburg, Baden Württemberg, Germany, [2]Gastroenterology, University Hospital Freiburg, Freiburg, Baden Württemberg, Germany

Introduction: Patients with progressive liver cirrhosis develop a hyperdynamic syndrome with increasing cardiac output and heart rate in association with a reduction of blood pressure and systemic vascular resistance [1,2]. In a healthy person, blood flow over the portal vein represents nearly 80% of the total liver circulation. In liver cirrhosis patients flow volume and flow velocity is decreasing because of structural change and fibrosis. Doppler Ultrasound (US) studies showed significant correlation of portal vein circulation and velocity with the stage of liver disease in liver cirrhosis patients [3,4]. Contrast-enhanced and non-contrast-enhanced MRI techniques have been applied in several studies for the evaluation of the degree of cirrhosis and portal hypertension in the portal venous system [5,6]. The aim of this study was to visualize and quantify portal vein hemodynamics using a flow-sensitive 4D MRI at 3 Tesla for an improvement of diagnostic information in liver cirrhosis patients.

Methods: We evaluated 3D flow characteristics in the portal vein, using time-resolved 3D MR velocity mapping at 3T MRI (TRIO, Siemens, Germany) in a group of 12 liver cirrhosis patients (age=55.1±10.2), 20 young volunteers (age=27.8±0.5) and 20 age matched volunteers (age=58.6±0.5). For minimizing artefacts respiratory gating with a navigator at the spleen-lung interface and ECG gating were applied. An axial oblique 3D volume was acquired with three-directional velocity encoding (venc = 50cm/s) and a spatial resolution of 1.6 x 2.1 x 2.4mm3, flip angel 7°, TE=3.0ms, TR=44.8ms, and temp. res. = 45ms. Evaluation of flow in the portal venous system was performed by 3D visualization (EnSight, CEI, Apex, USA) [7,8] and included 3D streamlines and time-resolved particle traces originating from 6 emitter planes precisely placed at anatomical landmarks in the portal vein system (fig. 1). Semi-quantitative grading of the streamlines and particle traces images was performed according to visualisation of the vessels, leakage into adjacent vessel system, maximum flow distribution in the portal vein and type of inflow into the splenic-mesenteric confluence (table1). Quantitative analysis included vessel lumen segmentation and flow quantification with retrospective extraction of regional peak and mean velocities and vessel area using a home built tool (Matlab, TRhge Mathworks, USA). Results were compared to the reference standard US.

Results: Visualization of 3D streamline and particle trace in the portal venous hemodynamics could successfully be achieved for all patients and volunteers with a slight restriction in the left intrahepatic portal vein branch (table 1). Inflow into the splenic-mesenteric confluence was most frequently in the caudal and cranial part by blood flow originating from the mesenteric and splenic vein, respectively. 3D blood flow visualization in the patients demonstrated normal flow patterns (tab. 1, fig. 2). There was no significant difference for flow volume within the 3 groups. In all emitter planes of the portal venous system a persistent reduction of the peak velocities was seen from the young volunteers (age group 1), old volunteers (age group 2) to the patients (table 3). In the MRI measurements the reduction of the peak velocities was up to 38.10 % between patients and young volunteers and up to 18.75% between patients and old volunteers. In comparison in the US a reduction of the peak velocities of 35.3% between patients and young volunteers and up to 33.3% between patients and old volunteers was seen. The correlations for the peak and mean velocities between MRI and the US were significant (r=0.53, p< 0.001).

Discussion: The results in our study reveal a qualitative and quantitative evaluation of comprehensive 3D flow hemodynamic in the portal system of liver cirrhosis patients in correlation to the standard US. Comparable to lower velocity values of liver cirrhosis patients in MRI and US measurements [9,10] a persistent reduction of the peak velocities was seen for the patients compared to the volunteers with a significant correlation for the peak and mean velocities between MRI and US. As a result 3D MR velocity mapping may be a standardized technique for detecting pathological changes in flow characteristics, therapy monitoring or disease progression in cirrhosis patients.

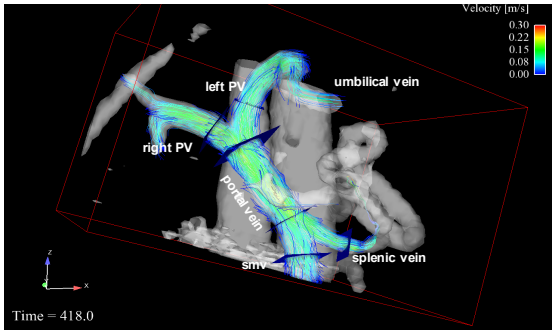

Figure 1: Slines Visualization of portal venous flow of a patient with a re-opened umbilical vein and flow over the left PV branch. Emitter planes positioned in the sup. mes. and spl. vein, dist. and prox. mes.-spl. confluence. and right and left intra-hep. portal vein branch.

Flow visualization slines	complete vis.	Velocity distribution	
superior mes. vein	100.0%	isolated flow acceleration in streamlines	27.8%
splenic vein	98.1%	isolated flow acceleration in particle traces	25.9%
spl.-mes. con. prox.	100.0%		
spl.-mes. con. distal	100.0%	most often flow distr. in splenic-mesenteric confluence	
right intrahep. branch	96.2%	(smv/ splenic v.)	
left intrahep. branch	86.5%	caudal / cranial	37.3%
		dorsal / ventral	27.5%
leakage	yes in 96.2%	dorsocaudal / cranioventral	23.5%

Table 1: Summary of the results of the qualitative image grading

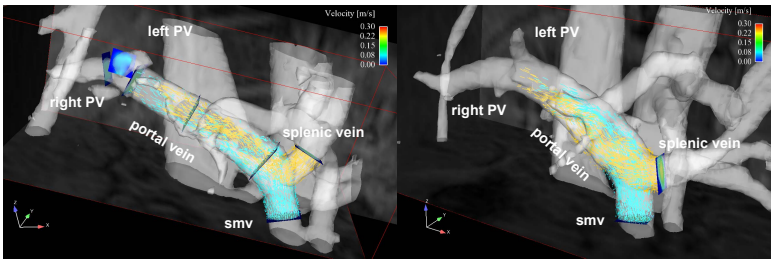

Figure 2: 3D particle traces color coded according to their vascular origin (yellow = splenic vein, blue: sup. mes. vein) **LEFT:** Typical homogenous filling with clearly separated flow channels **RIGHT:** Helical mixing.

	MRI peak velocity [m/s] mean ± SD	US peak velocity [m/s] mean ± SD	MRI mean velocity [m/s] mean ± SD	US mean velocity [m/s] mean ± SD
splenic vein	0,21 ± 0,05	0,24 ± 0,05	0,10 ± 0,02	0,11 ± 0,03
smv	0,17 ± 0,07	0,31 ± 0,11	0,08 ± 0,03	0,14 ± 0,04
splenic-mesenteric	0,23 ± 0,08	0,35 ± 0,10	0,11 ± 0,03	0,15 ± 0,04
right intrahep. branch	0,18 ± 0,05	0,24 ± 0,05	0,08 ± 0,02	0,11 ± 0,02
left intrahep. branch	0,14 ± 0,03	0,18 ± 0,06	0,07 ± 0,02	0,08 ± 0,03

Table 2: MRI flow quantification results compared to Doppler US

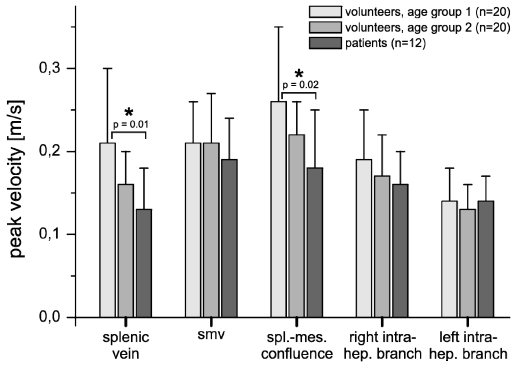

Table 3: peak velocities from 5 emitter planes of the portal venous system between volunteers, age group 1 and age group 2 with a significant correlation (r=0.53, p< 0.001)

References: **1.** Groszmann RJ. Hepatology. 1994;20:1359–1363. **2.** Kowalski HJ et al.. Am J Med Sci. 1954;228:622–625. **3.** Drazen Z et al.. Dig Dis Sci. 2009. **4.** Taourel P et al.. Hepatology. 1998;28:932–936. **5.** Barthelmes D et al.. Eur J Gastroenterol Hepatol. 2009; 21:693-700. **6.** Ito K et al.. J Magn Reson Imaging. 2009; 29:1224-9. **7.** Kronzon I, et al.. Circulation. 2006;114:63-75. **8.** Markl M, et al.. J Magn Reson Imaging 2007;25:824-831. **9.** Sugano S et al.. J Gastroenterol. 1999; 34:613-8. **10.** O'Donohue J et al.. Eur J Gastroenterol Hepatol. 2004; 16:147-55.