Quantitative assessment of splenic hemodynamics at 4D flow MRI in the evaluation of thrombocytopenia: A pilot study in cirrhotic patients with portal hypertension

Jad Bou Ayache[1], Zoran Stankovic[1], Edouard Semaan[1], James C Carr[1], Michael Markl[1], and Jeremy D Collins[1]
[1]*Radiology Department, Feinberg School of Medicine, Chicago, Illinois, United States*

Purpose: Thrombocytopenia predisposes patients with bleeding, which can be spontaneous and life threatening. An important treatable cause of thrombocytopenia is hypersplenism, or splenic sequestration associated with splenomegaly[1]. Partial splenic embolization (PSE) has emerged as a preferred treatment over splenectomy. Particle embolization is performed to reduce the splenic volume by 50-70% at PSE, aiming to maintain the vital filtration function of the spleen while reducing the sequestration effect on platelets[2]. At PSE the amount of particulate embolics necessary to reduce splenic perfusion to the target is highly variable and angiographic estimates of the infarcted splenic volume are inaccurate without cone beam CT. Prior studies evaluated Doppler US to assess the effect of PSE on portal hemodynamics aiming to improve portal hypertension; however, difficulties assessing the vessel area limit the accuracy of this technique. 4D flow MRI is an emerging modality for volumetric 3D flow visualization and quantification in the abdomen and is well suited to evaluate splenic hemodynamics.
We therfore aimed to study the baseline splenic arterial and venous blood flow using 4D flow MRI in patients with splenomegaly. We hypothesize that splenic arterial and venous blood flow, normalized to splenic mass, will be higher in patients with thrombocytopenia compared to patients without thrombocytopenia.

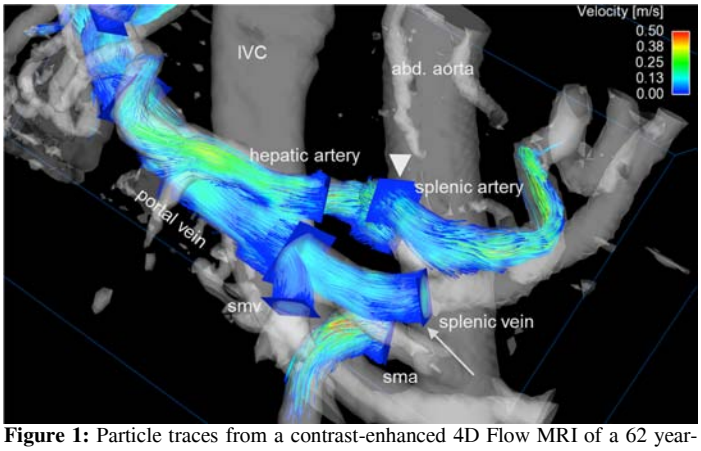

Figure 1: Particle traces from a contrast-enhanced 4D Flow MRI of a 62 year-old female with cirrhosis and portal hypertension demonstrating the positioning of emitter planes in the splenic artery (arrowhead) and splenic vein (arrow).

	Post-Contrast		Non-Contrast		
Platelet Count (*10^3)	**Average Flow Index (mL/min/100g splenic tissue)**				**Mean Spleen Volume (g)**
	Splenic Artery	**Splenic Vein**	**Splenic Artery**	**Splenic Vein**	
>150	42.4	17.2	47.4	25.4	621.8
50-150	53.7	27.8	52.0	58.5	479.7
<50	88.6	54.6	95.1	73.4	1385.0

Table 1: Indexed splenic artery and vein flows at non- and contrast-enhanced 4D flow MRI stratified by the peripheral platelet count, compared to the mean splenic volume.

Methods: The study cohort consisted of 9 prospectively recruited patients (age=58.0±4.7yrs, 2 women) with liver cirrhosis and portal hypertension diagnosed on routine abdominal MR imaging. All subjects underwent 4D flow MRI at 3T (MAGNETOM Skyra, Siemens Medical Systems, Erlangen, Germany). ECG- and respiratory navigator gated 4D flow MRI was acquired in an axial oblique imaging volume including the splenic artery and splenic vein with the navigator positioned at the lung-spleen interface, lateral to the heart. Pulse sequence parameters were as follows: spatial res=2.5x2.1x3.0mm^3, temporal res=40.8msec, α=15°, TE=2.7msec. 4D flow MRI was performed with velocity sensitivity of 50 and 100 cm/sec for splenic vein and splenic artery flow quantification respectively, before and after the administration of 0.03 mmol/kg gadofoveset trisodium (Ablavar, Lantheus Medical Imaging, Billerica, MA). Pre-processing was performed including noise filtering, anti-aliasing and eddy current correction. Splenic artery and splenic vein flow visualization was performed using time-resolved pathlines (EnSight, CEI, Apex, USA) originating from emitter planes placed in the proximal to mid splenic artery near the mid body of the pancreas and the mid splenic vein (Figure 1). Flow quantification was performed by net flow over the cardiac cycle in retrospectively positioned 2D analysis planes. Splenic volumes were measured on breath-held axial balanced steady state free precession (bSSFP) images using a 3D workstation (Vitrea, Vital Images, Minneapolis, MN). Clinical laboratory data was obtained from the electronic medical record. Severity of liver disease was assessed with the MELD and Childs-Pugh scores. Non- and post-contrast splenic artery and splenic vein flows (mL/min) were indexed to 100g splenic volume. Patients were into platelet counts of <50*10^3, 50-150*10^3, and > 150*10^3. A Pearson correlation was performed between the indexed flows and the platelet count. Non- and post-contrast indexed flows were compared using the student's t-test across the entire cohort.

Results: Pre-and post-contrast 4D flow MRI was successfully performed with and analyzed in all subjects. Seven and two patients had Childs-Pugh Class A and B cirrhosis respectively. The average MELD score was 6 (range 0-14). The indexed splenic artery and vein flow increased significantly ($p<0.05$) as the platelet count decreased for both non-contrast and post-contrast 4D flow MRI acquisitions (Table 1), with greater absolute within-group differences noted for the indexed splenic artery flows. Changes in splenic volume alone were not sufficient to predict thrombocytopenia. There were no significant differences between non- and post-contrast splenic artery or non- and post-contrast vein flow indexes ($p=0.69$, $p=0.05$, respectively). Pearson correlations between the platelet count and the non-contrast splenic artery and vein indexed flows were -0.87 and -0.56; correlations with post-contrast indexes were -0.61 and -0.53, respectively.

Discussion: Indexed splenic artery and vein flow demonstrated significant differences between patients without and with various degrees of thrombocytopenia. These differences were seen for both non- and contrast-enhanced 4D flow MRI acquisitions, demonstrating the feasibility of this technique in patients who cannot receive gadolinium-based contrast media. Our preliminary study demonstrates that splenic arterial and venous flow increases dramatically in splenomegaly, far above what would be expected from increases in splenic size alone. This relationship suggests a hemodynamic mechanism to explain the thrombocytopenia seen in patients with splenomegaly and explains the therapeutic effect of partial spleen embolization in restoring the peripheral platelet count.

Conclusions: Increased splenic flow quantified at non-contrast or contrast-enhanced 4D flow MRI in cirrhotic patients with portal hypertension correlates negatively with the peripheral platelet count and may explain the various degrees of thrombocytopenia in this patient cohort.

Acknowledgements: Grant support by RSNA Research and Education Foundation (JD Collins, RSD# 1218); German Research Association (Z Stankovic, STA1288/2-1).

References: 1. Ikura Y et al. Am J Med Sci 2013;346:199-203. 2. Chikamori F et al. Hepatogastroeneterology 2007;54:1847-9.