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

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Purpose: An important treatable cause of thrombocytopenia is hypersplenism or splenic sequestration[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. Identifying patients with hypersplenism likely to respond to PSE is challenging. 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 hypothesize that splenic arterial and venous blood flow, normalized to splenic volume, will be higher in patients with compared to patients without thrombocytopenia.

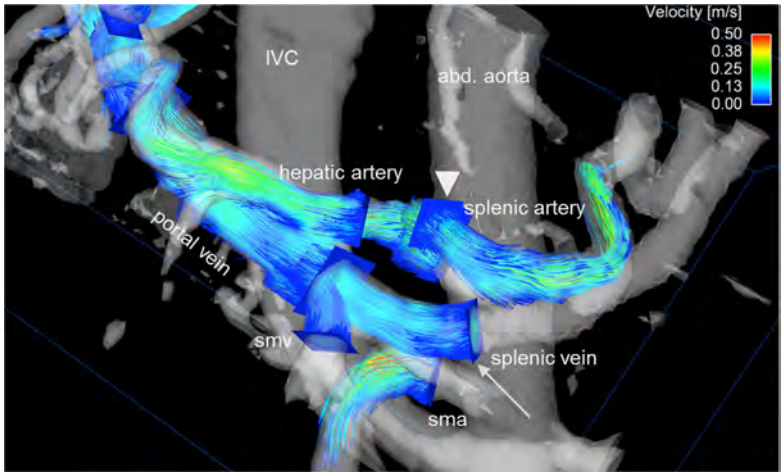

Figure 1: Particle traces from a contrast-enhanced 4D Flow MRI of a 62 year-old female with cirrhosis and portal hypertension demonstrating the positioning of emitter planes in the splenic artery (arrowhead) and splenic vein (arrow).

Methods: The study cohort consisted of 26 prospectively recruited patients (age=59.4±7yrs, 7 women) with liver cirrhosis and portal hypertension. All subjects underwent 4D flow MRI at 3T (MAGNETOM Skyra, Siemens Medical Systems, Erlangen, Germany) with ECG- and respiratory navigator gating in an axial oblique imaging volume including the splenic artery and splenic vein with the navigator positioned at the lung-spleen interface. Pulse sequence parameters were as follows: spatial res=2.5x2.1x3.0mm^3, temporal res=40.8msec, α=7°, TE=2.7msec, k,t-GRAPPA R=5. 4D flow MRI was performed with a velocity sensitivity of 50 and 100 cm/sec for splenic vein and splenic artery flow quantification respectively, without contrast. 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 MELD and Childs-Pugh scores. Splenic artery and vein flows (mL/min) were indexed to 100mL splenic volume. Patients were stratified into platelet counts of <50*10^3, 50-150*10^3, and > 150*10^3 for analysis.

Platelet Count (*10^3)	Flow Index#		Mean Spleen Volume (mL)
	Splenic Artery	Splenic Vein	
>150	76.3 ± 38.1	36 ± 17.8	568.7 ± 239.8
50-150	59.9 ± 26.7^	24.3 ± 15.9*	714 ± 320.2
<50	88.8 ± 2.8^	49 ± 7.9*	1084 ± 425.6

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. #Flow index (mL/min/100mL splenic tissue); ^,* significant differences (p<0.05)

Results: 15, 7 and 4 patients had Childs-Pugh Class A, B, and C cirrhosis respectively. The average MELD score was 11 (range 0-23). The indexed splenic artery and vein flow increased significantly (p<0.05) as the platelet count declined below 50*10^3; whereas reduced indexed splenic artery and splenic vein flows were noted in mild thrombocytopenia (Table 1). Greater absolute within-group differences noted for the indexed splenic artery flows. Changes in splenic volume alone were not sufficient to differentiate mild from severe thrombocytopenia.

Discussion: Indexed splenic artery and vein flow demonstrated significant differences between patients with mild and severe thrombocytopenia at non-contrast 4D flow MRI acquired at 3T. Splenic arterial and venous flow increased dramatically in patients with severe thrombocytopenia, far above what would be expected from increases in splenic size alone; lower splenic vein indexed flows are related to the presence of portosystemic shunting proximal to the location of flow quantification in the vein. This relationship suggests a hemodynamic mechanism to explain the thrombocytopenia seen in patients with splenomegaly and provides a theoretical construct for the therapeutic effect of PSE in restoring the peripheral platelet count.

Conclusion: Quantitative assessment of splenic hemodynamics using non-contrast 4D flow MRI is a promising technique for identifying patients with hypersplenism as an etiology of thrombocytopenia.

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

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