4D-flow MRI for risk stratification of gastroesophageal varices in cirrhotic patients

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Target audience: Clinicians and scientists interested in portal hypertension and liver imaging

Background and Purpose: Portal hypertension leads to the dreaded complication, gastroesophageal varices. Currently, endoscopy is the only available technique to evaluate risk of variceal rupture. However, endoscopy is relatively invasive and requires sedation. 4D flow MRI methods have recently been validated for comprehensive mapping of arteries and portal vessels in cirrhotic patients[1-3]. In this study, we aimed to determine the potential utility of morphological and quantitative assessment with 4D flow MRI for stratifying the risk of variceal rupture in cirrhotic patients using endoscopy as the standard of reference.

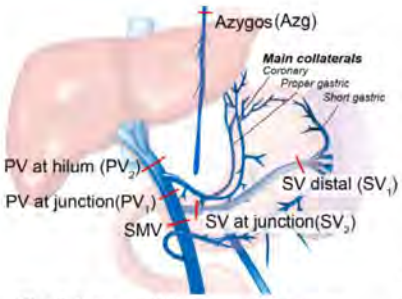

Fig 1 *Points of flow measurements.*

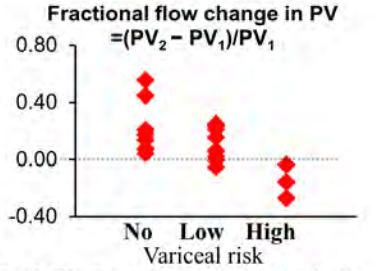

Fig 2 *PV flow shunts increasingly into varices in cases with high variceal risk.*

Methods: ***4D flow MRI acquisition:*** Twenty-one patients (mean age, 53.8 years) were recruited. Studies were conducted on a clinical 1.5T or 3T scanner (GE Healthcare, Waukesha, WI). 4D velocity mapping was achieved using a radially undersampled phase contrast acquisition (4D flow MRI) with increased velocity sensitivity performance[4] and comprehensive coverage of the upper abdomen. MR parameters included: imaging volume: 32x32x24cm spherical, 1.25mm acquired isotropic spatial resolution, TR/TE=6.4/2.2ms, VENC=30cm/s. All subjects received 0.1mmol/kg of gadobenate dimeglumine (Multihance, Bracco, Italy) and were scanned in the delayed phase after a clinical dynamic scan.

Flow measurements of 4D flow MRI: Manual placements of cut-planes were performed to measure blood flow in the targeted 6 segments (Fig.1, red lines) using EnSight (CEI, Apex, NC). ***Visual assessment of 4D flow MRI:*** Vessel segmentation was performed in MIMICs (Materialize, Leuven, Belgium) from PC angiograms for visual assessment. A radiologist reviewed all 4D flow MRI angiograms to determine visibility of gastroesophageal varices, main collaterals (coronary vein, proper and short gastric vein) which are related to gastroesophageal varices development, and other collaterals (umbilical vein, splenorenal shunts).

Standard of reference for variceal risk: A gastroenterologist categorized the risk of varices by endoscopy; **no risk** = no varices found on endoscopy; **low risk** = varices with small size (≤5mm) and no mucosal surface markers (red wale sign and/or nipple sign); **high risk** = varices either large (>5mm) or positive for surface markers. High risk varices required endoscopic treatment due to an elevated risk of rupture. ***Statistical analyses:*** Spearman's correlation coefficient (ρ) was used to assess correlation between measured flow and variceal risk. To identify shunting from the portal vein into the coronary vein and into gastroesophageal varices, we calculated the fractional flow change in PV= $(PV_2 - PV_1)/PV_1$, where PV_1 and PV_2 are the proximal and distal portal blood flows (ml/min), respectively, (Fig.1). To identify significant variables, which may predict variceal risk, the results of flow measurements, visual assessment as well as patients' clinical demographics were evaluated using Cochran-Armitage trend test.

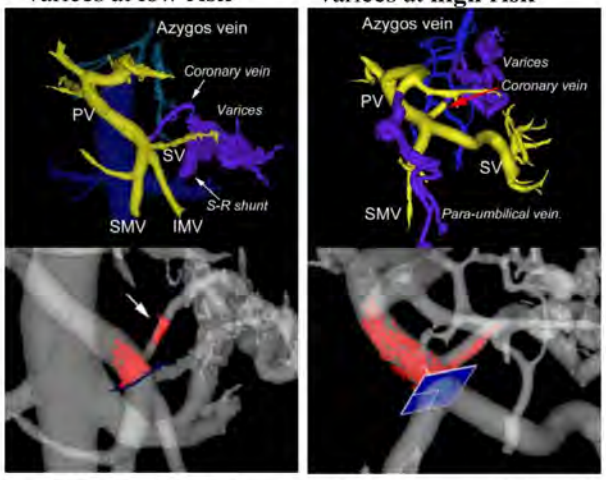

Fig 3 *Coronary blood flows toward liver in case with low risk varices (left), whereas toward varices in high risk case (right). Varices and collaterals are visible in both cases.*

Table 1. Trend analysis to identify predictor of variceal risks

	No risk	Varices Present		p value
		Low risk	High risk	
No	7	9	4	-
Age>65	2 (29%)	4 (44%)	1 (25%)	0.974
Female	2 (29%)	4 (44)	2 (50%)	0.451
Prior bleeding	0 (0%)	1 (11%)	2 (50%)	**0.035**
MELD ≥10	4 (57%)	4 (45%)	1 (25%)	0.307
4D flow MRI				
Visible varices	0 (0%)	3 (33%)	1 (25%)	0.218
Main collateral	1 (15%)	5 (56%)	2 (50%)	0.167
Collateral others	1 (15%)	3 (33%)	1 (25%)	0.594
Fractional flow change in PV<0	0 (0%)	2 (22%)	4 (100%)	**0.001**

Results: A significant correlation between measured flow and variceal risk was observed for fractional flow change in the PV (ρ= -0.60, p=0.006, Fig.2). For flow measurement of single vessels, correlation was not significant (ρ=-0.25─0.30, all p>0.20). A cutoff value of <0% was set to make a binary decision for fractional flow change in PV, which is indicative of shunting into varices. Among the variables examined, a significant trend was observed in prior history of bleeding (p=0.035) and fractional flow change in PV (p=0.001). (Table 1 and Fig.3) Fractional flow change of <0 yielded 100% (4/4) sensitivity and 88% (14/16) specificity for distinguishing patients with high risk varices from others.

Conclusion: Flow measurement with 4D flow MRI is useful indicator of gastroesophageal variceal risk.

References: 1) Roldán-Alzate JMRI 2013;37:1100-8. 2) Stankovic Z, et al. Radiology 2012; 262:882-73. 3) Frydrychowicz A, et al. JMRI 2011; 34:577-84. 4) Johnson MRM 2010;63:349-55. **Acknowledgement:** We acknowledge the support of the NIH (R01DK096169) and GE Healthcare.