Non-contrast indirect MRI Quantification of Portal Hypertension severity

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Target audience: Gastroenterologists and liver imaging researchers.

Purpose: Portal hypertension (PH) is a frequent syndrome in patients with chronic liver diseases and it is characterized by an increased liver resistance to blood flow. The increased resistance induces a rise in the portal pressure gradient (PPG), leading to hepatic hemodynamic changes: decreasing the relative contribution of portal vein and increasing the relative contribution of hepatic artery to liver perfusion. The relevance of portal hypertension derives from the frequency and severity of its complications, which represent the first cause of hospital admission, death and liver transplantation in patients with cirrhosis[1]. It has been suggested that the measure of the severity of PH should be evaluated in all patients with chronic liver diseases as a surrogate marker of the liver chronic damage and the response to treatments. The currently favored method for determining portal venous pressure involves catheterization of the hepatic vein and measurement of the hepatic venous pressure gradient (HVPG)[2]. However this method is invasive, expensive, and probably not suitable to screen asymptomatic high-risk patients. In this work we propose to indirectly measure the severity of PH by estimating the portal vein blood volume that flows into the intrahepatic circulation (IHPVBV) in a certain number of heart cycles. The rationality of this idea comes from the concept that PPG (like the gradient pressure in any vascular system) is determined by the product of portal vein flow (Q) and the liver vascular resistance (R), Fig. 1[3]. Therefore, the measurement of the intrahepatic blood volume that flows in a certain number of heart cycles would be a good estimation of the P/R ratio and indirectly of the severity of PH. In order to quantify the IHPVBV in one and two cardiac cycles we use the technique called TIR-ASL[4], which is a flow dependent non-contrast technique, that does not require a subtraction step as classic arterial spin labelling (ASL) methods, and could be easily adapted to evaluate the IHPVBV in one or two heart cycles[5].

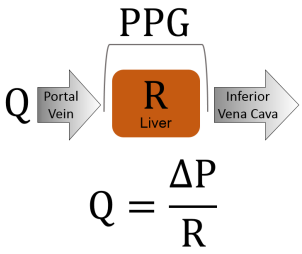

Fig. 1. Q, R and PPG schematic representation.

Methods: TIR-ASL sequence[4,5] was used to quantify the IHPVBV during one and two cardiac cycles. TIR-ASL uses a Triple Inversion Recovery pre-pulse and exploits the ability of the two non-selective Inversion-Recovery pre-pulses to null background signal while maintaining the signal of labeled blood using a regional inversion pulse. With the optimal selection of the inversion times TI1 and TI2, it is possible to null the static tissue and just keep the signal of the targeted blood. This sequence can be used either in one or two heartbeats interval, obtaining the same effect but increasing the labeling time (TI1+TI2). We estimated IHPVBV by the segmentation of the intrahepatic portal vein pixels based in their intensity using homemade Matlab software. We corrected these measurements by the liver volume (LV) calculating the ratio IHPVBV/LV. We estimated LV and spleen volume (SV) using a 3D Inversion Recovery sequence with an inversion time of 600 ms. We tested this protocol in 20 healthy volunteers (75% male, age range: 23-66) and 10 patients with chronic liver disease and portal hypertension (50% male, age range:44-73). All the images were obtained on a 1.5T Achieva MR scanner (Philips Healthcare, Best, NL). Statistical analysis was performed using Mann-Whitney independent-samples test, and receiver operating characteristic (ROC) analysis.

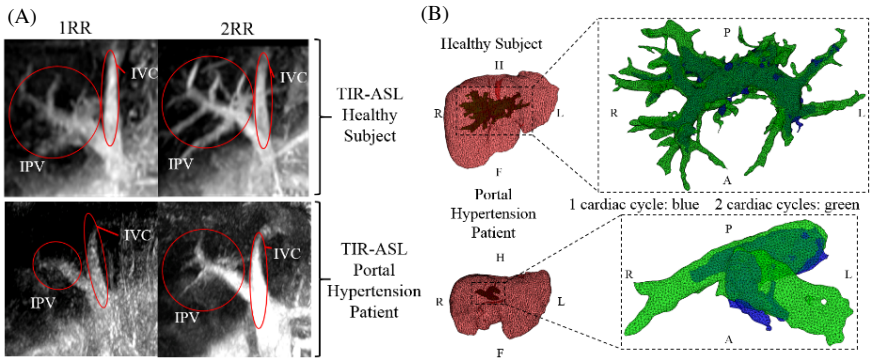

Figure 2. (A) 3D Maximum Intensity Projections (MIP) reconstruction of an intrahepatic portal vein. (B) Compared 3D reconstruction of the intrahepatic portal vein volume in one (blue) and two (green) cardiac cycles in a healthy subject and in a PH patient, H: head, F: foot, R: right, L: left, P: posterior, A: anterior.

Results: We successfully quantified the IHPVBV in one and two heart cycles in the healthy volunteers and patients groups (Fig. 2A). We did not find statistical difference in the LV between groups, however the patients groups showed a smaller LV/SV ratio ($p<0.001$). There were significant differences in the IHPVBV/LV ratio measured in one and two heart cycles between both groups ($p<0.001$) (Figs. 2B, 3A), suggesting higher liver vascular resistance in the patients group. Morphological images showed that the LV/SV ratio could differentiate between healthy volunteers and PH patients with a sensitivity of 77% and specificity of 89% (cut of point:7.1). "Liver vascular resistance" images derived from IHPVBV/LV ratio in two heart cycles could differentiate them with a sensitivity of 82% and specificity of 100% (cut of point: 0.013). The combination of both parameters (morphology and resistance) can accurately differentiate both groups with sensitivity of 90% and specificity of 100% (Fig. 3B).

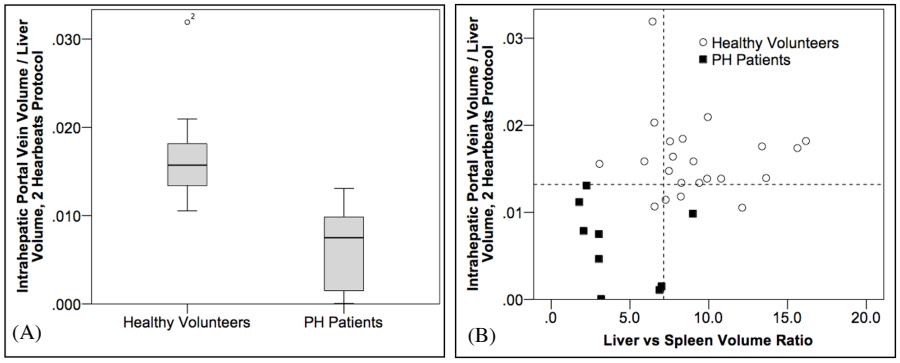

Figure 3. (A) Median and IQ range for IHPVBV/LV ratio in healthy volunteers and PH Patients. (B) IHPVBV/LV in two heartbeats and Liver/Spleen volume ratio in healthy volunteers and PH Patients can accurately differentiate both groups.

Discussion: Our results showed that it is possible to improve the non-invasive diagnosis of portal hypertension using morphological quantification and indirect estimations of the liver vascular resistance. This technique has the advantage of not requiring invasive methods neither contrast agent, and most of the quantification could be fully automatized with minimum human intervention.

References: 1. Bosch J et al. J Hepatol 2000. 2. Bosch J et al. Nat. Rev. Gastroenterol. Hepatol 2009. 3. Kapoor D et al. J Gastroenterol Hepatol 2002. 4. Andia M et al. MRM 2012. 5. Aguirre D et al. Procs. 22nd Internat. Conference of the ISMRM, Milan, 2014.