Quantification of liver perfusion using multi-delay Pseudo-Continuous Arterial Spin Labeling

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Target audience: Hepatologists, radiologists and MRI researchers interested in liver perfusion imaging.

Introduction: Chronic liver diseases can lead to liver fibrosis and cirrhosis, which potentially may cause liver cancer. Many conditions of liver disease can be monitored and detected by liver perfusion MRI [1]. Pseudo-continuous Arterial Spin Labeling (pCASL) is a non-invasive MRI technique that has been widely applied for brain perfusion imaging. However, its application on body organs and in particular for liver perfusion imaging has been limited. The goal of this study was to determine the feasibility for quantitative liver perfusion measurements of the hepatic artery and portal vein respectively using a multi-delay pCASL protocol.

Methods: MRI scans were performed on 4 healthy volunteers on a MAGNETOM Trio 3T MR Scanner (Siemens AG, Erlangen, Germany) using a customized pCASL sequence with a navigator-gated, True-FISP readout [2]. Two series of multi-delay pCASL scans were performed to measure the blood flow from the hepatic artery and hepatic portal vein respectively, by selectively labeling the descending aorta and the portal vein accordingly (see Fig. 1). The plane 1 labels the blood in the hepatic artery while the plane 2 labels the blood in both the hepatic artery and portal vein. A single coronal slice was acquired with the following imaging parameters: field of view = 350mm, matrix = 128*128, slice thickness = 8mm, labeling duration = 1500ms, 30 acquisitions (15 pairs label/control images) for each post-labeling delay (PLD), 5 or 6 PLDs between 200 and 2500ms. The navigator was placed on the right diaphragm without intersecting with the imaging plane.

Motion correction was performed offline using the advanced normalization tools (ANTS: http://www.picsl.upenn.edu/ANTS). ANTS employed a cross-correlation-based symmetric diffeomorphic transformation between the average template and the target time series images to correct both rigid and non-rigid motion [2]. Perfusion-weighted images were generated by pairwise subtraction of motion-corrected label and control images. Spikes in the difference image series were removed once identified as beyond 2 standard deviations from the mean and an average perfusion weighted image was generated for each PLD [2]. Several hand-drawn region of interest (ROIs) including both liver tissue and vasculature were used for measuring the mean difference signals (dM), which were used to fit blood flow and arterial transit time based on a kinetic model (Eq [1] in ref [3]).

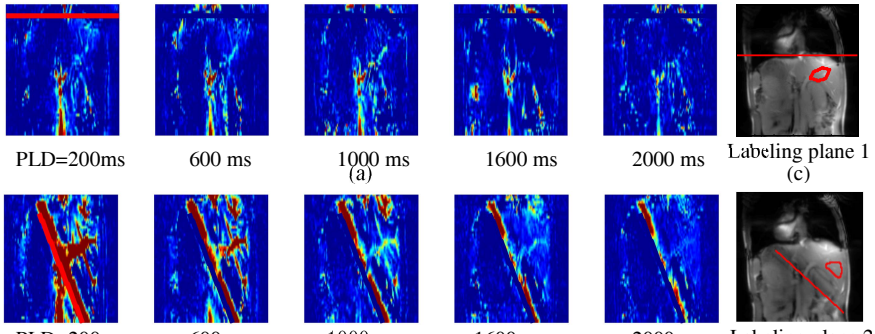

Figure 1 Perfusion-weighted images at multiple PLDs. Aorta labeled:(a); portal vein labeled:(b). Anatomical illustration of labeling plane for aorta (c) and portal vein (d) along with ROIs (red)

Results: A typical example of the series of perfusion-weighted images across multiple PLDs is shown in Fig. 1. Liver perfusion can be seen in long PLD (>=1.6s) images especially for portal vein labeling. Estimated mean blood flow of hepatic artery labeled (44 ± 14) and hepatic portal vein labeled (140 ± 9)ml/(100ml *min) along with the corresponding arterial transit times ($1020\pm396, 1892\pm164$ ms) are shown in Table 1.

Discussion: Liver blood supply consists of both hepatic artery and hepatic portal vein, where hepatic artery accounts for about 25% of the blood supply, hepatic portal vein accounts for about 75% of the blood supply. The literature value of hepatic artery blood supply is around 20 ml/(100ml*min), and 102 ml/(100ml*min) for hepatic portal vein [4]. The blood velocity in hepatic artery is slightly higher than that of hepatic portal vein, which results in a smaller arterial transit time in hepatic artery than in hepatic portal vein. The result of perfusion measurement using multi-delayed pCASL shows good accordance with the literature. According to the labeling scheme in the experiment, the blood flow in the hepatic portal vein (both hepatic portal vein and hepatic artery were labeled) should be ~4 times the value of the blood flow in the hepatic artery, which is generally consistent with the model fitting results. The capability to noninvasively and selectively label the hepatic artery and portal vein is a unique strength of pCASL as compared to other liver perfusion imaging techniques such as CT perfusion and dynamic contrast enhanced MRI. In the future, the reliability of liver perfusion imaging using multi-delay pCASL should be improved that will allow clinical applications in liver diseases.

Table 1 Comparison of in vivo data and estimated data

	Blood flow (ml/(100ml*min))		Arterial Transit Time (ms)	
	Hepatic artery labeled	Portal vein labeled	Hepatic artery labeled	Portal vein labeled
Subject 1	34	132	1418	1976
Subject 2	63	137	1292	2033
Subject 3	46	153	770	1897
Subject 4	32	138	601	1660
Mean±SD	44±14	140±9	1020±396	1892±164

References: [1] Hoad C, et al. ISMRM 2011; 794 [2] Wang DJ, et al. MRM 64:1289-1295(2010) [3] Wang J, et al. MRM 48:242-254(2002). [4] Weidekamm, et al. AJR: 184, 2005: 505-510.