Inflow velocity density mapping using Fourier Analysis of Velocity Selective ASL images

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Target audience: Scientists interested in brain hemodynamics, MR engineers interested in arterial spin labeling and physicians interested methods to examine the health of the brain's vascular system.

Introduction: Blood Flow is an important biomarker of brain tissue health. Arterial spin Labeling (ASL) techniques can produce perfusion images without using contrast agents. Velocity selective ASL (VSASL) labels inflowing arterial water by saturating spins traveling above a specified velocity threshold. Previous work [1] suggests that the distribution of blood flow velocity irrigating a given tissue can be inferred using VSASL. Here, we demonstrate how Inflow Velocity Density Mapping (IVDM) can be achieved in greater detail by manipulating the velocity selective labeling profiles in VSASL, such that the observed signals constitute a Fourier transform of the blood flow velocity distribution. The resulting IVDM produces histograms of the arterial velocity distribution in the arteries feeding a voxel. The method can be used to evaluate the status and health of the blood supply to the brain tissue.

Methods: A velocity selective ASL sequence [2] was used to collect images, as follows. A BIR-8 pulse (with Δ = 0.61 ms, δ = 0.305 ms,) was applied followed by a delay (TI = 1300ms.) to label the arterial blood supply to the tissue. Arterial signals were crushed using a second velocity selective saturation pulse (BIR-4, velocity > 4 cm/s) immediately before acquisition with a spiral acquisition sequence (TR = 5s, TE = 5ms, matrix = 64 x 64, thickness = 8 mm).

Inflow velocity density encoding was achieved by collecting a series of such VSASL images over a range of velocity encoding gradients (VENC = 0:9:72 cm/s), which produced a cosine-shaped velocity encoding profile, as in [1]. A second series was collected using a modified BIR-8 pulse that produces a sine-shaped velocity encoding profile. The sine profile velocity encoding profile was obtained by including a 90-degree phase shift ($\Delta\phi$) in the last segment of the BIR-8 pulse, which tips the spins back to the xz-plane [3]. As a result, the longitudinal component of the magnetization depends on the sine of the velocity. The two series (cosine and sine velocity profiles) were combined into a *complex* Fourier series. T1 and T2 relaxation effects were also included into the model. Finally, the velocity density distribution of the blood supply was calculated by the inverse Fourier Transform of the series. The experiment was repeated with and without the use of background suppression [4].

Results: The inflow velocity density map is shown in Fig. 1 (above: Background suppression (BS) on, bottom: off), frames correspond to 0:9:72 cm/s from left to right. CSF signals can be observed at 0 cm/s frame, but are significantly reduced when BS is on, but appears dark on frames of velocity > 0, which is consistent to reality since CSF dominates these region, and is very low velocity. The bright spots on high velocity frames indicate the locations of arteries. Some CSF signal is observable in the high velocity maps, likely due to wrap-around effects of under-sampling the Fourier series.

Fig. 2 shows the velocity distribution at the voxel indicated by the asterisks in the frontal region on the zero velocity frames of Fig. 1. The trend of the curve is consistent with the known distribution of arterial diameters: i., e., he majority of the arterial blood volume is in the arterioles and capillaries where blood flow velocities are low.

Figure 1. Velocity Density Map 0:9:72 (cm/s)

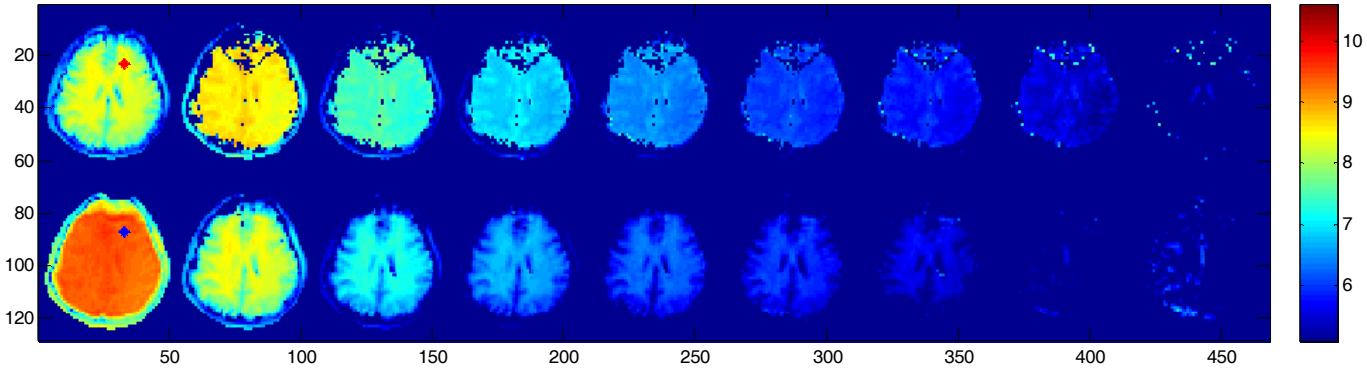
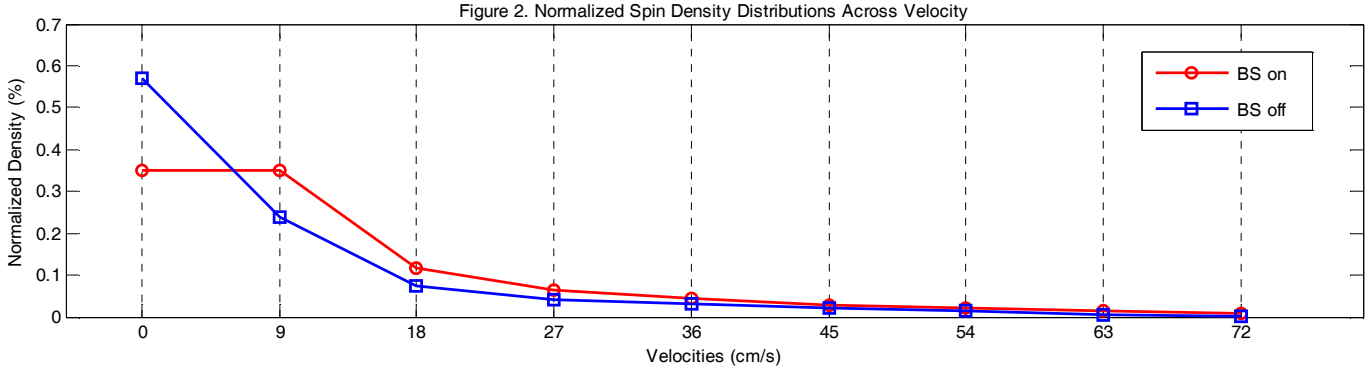


Figure 2. Normalized Spin Density Distributions Across Velocity



Discussion/Conclusion:
IVDM is a promising technique to measure and evaluate the arterial blood supply to brain tissue. The preliminary data presented here are consistent with existing knowledge of normal brain vasculature. Further investigation is needed to evaluate the robustness and validate the technique.

References:

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