Dynamic 3D Angiography with Pseudo Continuous Arterial Spin Labeling(PCASL) and Accelerated 3D Radial Acquisition

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INTRODUCTION: Cerebral vasculature filling patterns are highly useful for a number of clinical indications including AVMs, cerebrovascular steno-occlusive diseases, and aneurysms. CE-MRA can obtain filling dynamics, however, the attainable temporal resolution of CE-MRA is generally on the order of seconds and is limited by bolus dispersion of intravenous injection. Recently introduced ASL (PCASL) [1] techniques hold the potential of performing time-resolved angiography [2]; however, is currently limited to 2D projection imaging which suffers from SNR loss and extremely limited in 3D due to long scan times. We have previously presented a 3D PCASL angiography technique (PCASL-VIPR) [3] which exploits the sparse nature for accelerated static imaging. In this work, we investigate 3D non-contrast dynamic angiography with a modified PCASL-VIPR sequence with feasibility study results in healthy volunteers and AVM patients.

METHODS: The dynamic PCASL-VIPR sequence consists of a series of repeated segments with each composed of background suppression (BGS), PCASL, FAIR, and imaging modules as shown in Figure 1. To acquire dynamic inflow information, multiple states of PCASL are designed including one control state (for subtraction) and several tagging states which vary in the effective tagging duration (red in Figure 1) corresponding to the desired inflow timing. The segments with different states of PCASL are performed in an interleaved fashion to minimize the motion artifacts. Imaging is performed with low flip angle spoiled gradient echo (SPGR) with pseudo randomly acquired 3D radial trajectories (VIPR). PILS [4] is used to reconstruct each frame independently. Due to the averaging effect of radial sampling, highly accurate time-of-arrival maps can be determined by fitting the Bloch simulations to the time course of each voxel.

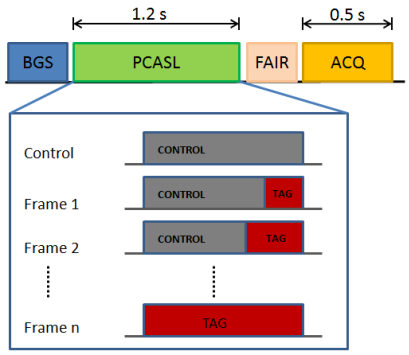

Figure 1. Pulse Sequence diagram shows four modules of a segment: BGS, multi-state PCASL (effective tagging duration shown in red), FAIR, and acquisition with time assignment.

A feasibility study has been done on both healthy volunteers and AVM patients in a 3.0T MRI scanner (MR750, GE Healthcare, Waukesha, WI, USA) with a 32-channel head coil. Dynamic inflow were obtained with a single dynamic PCASL-VIPR scan with the effective tagging durations of 0, 200, 400, 600, 800, 1000, and 1200 msec. Whole head coverage (22x22x16 cm^3) with a 3D isotropic resolution of 0.68 mm was obtained with a labeling plane just below the inferior edge of the imaging slab. The scan took 7 minutes with 3000 projections acquired for each frame.

RESULTS: Figure 2 shows the results from dynamic PCASL-VIPR of one healthy volunteer and one patient with AVM in the left brain. For better visualization, the sagittal MIPs of the left hemisphere were generated from each 3D time frame image for both subjects. In the images of the AVM patient, arterial blood filling starting from the Circle of Willis flowing through the two major feeding arteries and into the nidus of the AVM can be clearly observed with a temporal resolution of 200 msec. Excellent visualization of all the arterial vessels on both subjects can be appreciated with a 3D isotropic resolution of 0.68 mm and transparent background. The time-of-arrival maps present different filling time of every segment vessel in a single colorful image with the distal vessels showing a later filling time which matches our expectation.

DISCUSSION AND CONCLUSION: We have demonstrated that dynamic PCASL-VIPR is able to perform time-resolved 3D intracranial angiography with a 200 ms temporal resolution and a high 3D isotropic spatial resolution. With optimized sequence design and the acceleration provided by the VIPR radial trajectory, the entire exam can be completed with a single scan within 7 minutes.

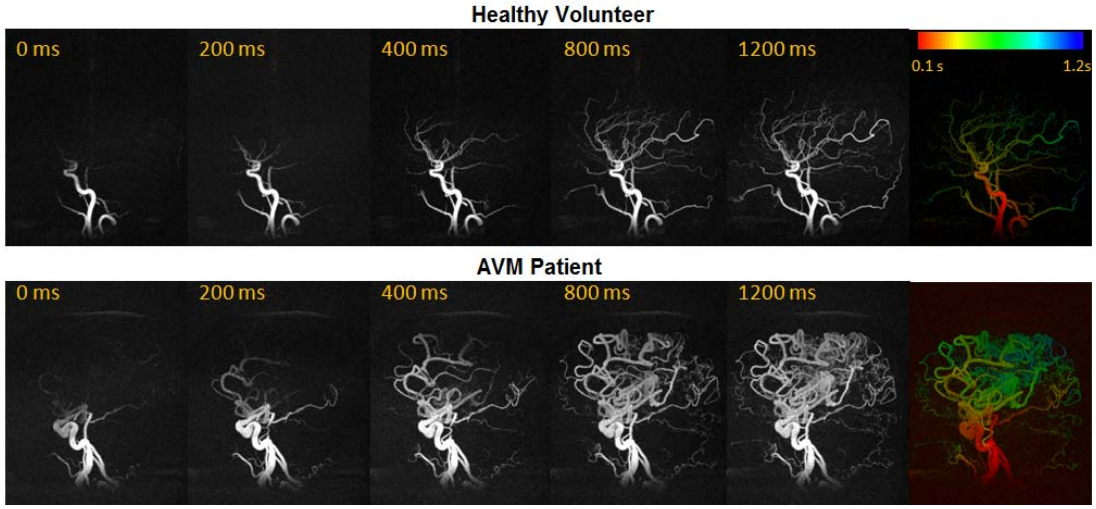

Figure 2. Sagittal MIPs of the left hemisphere of the healthy volunteer (top row) and the AVM patient (bottom row) show time-resolved inflow dynamics. Time-of-arrival maps show different filling times in color.

The dynamic data helps to create a global display of the arterial system. Our preliminary experience indicates that dynamic PCASL-VIPR is able to show differential filling rates in normal and pathological vessels and is particularly useful for delineating the arterial supply to AVMs.

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