Non-contrast enhanced time-resolved MR angiography with time-of-arrival mapping: A feasibility trial in cerebral AVM

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INTRODUCTION

Hemodynamic information is required for the accurate diagnosis, effective treatment, and follow-up examination of numerous diseases, e.g., cerebral arteriovenous malformation (AVM), to study the arterial feeding and draining veins of the pathologic nidus [1,2]. Clinically, such assessments are generally performed by X-ray digital subtraction angiography (DSA), which provides excellent temporal and spatial resolution, but this is an invasive procedures [3]. Recently, a new technique was presented for non-contrast volumetric time-resolved MRA (Contrast inherent INflow Enhanced Multi phase Angiography using pseudo-continuous arterial spin labeling; CINEMA-PCASL) [4]. This technique requires no catheter insertion or contrast agent and provides useful qualitative information on the morphologic and dynamic filling of intracranial vessels. The feasibility study of CINEMA-PCASL sequence has been reported recently on healthy volunteers, but its clinical application in patients with AVMs has not been conducted. The purpose of this study was to evaluate the diagnostic use of non-contrast time-resolved MRA with time-of-arrival map in patients with cerebral AVM.

METHODS

Fig 1. Schematic of the sequence for CINEMA-PCASL. CINEMA-PCASL technique combines multiple phases PCASL with 3D T1TFE sequence. Labeling geometry show imaging and background suppression slab (dashed line box), Labeling plane is indicated as red line.

Theory and Pulse Sequence: CINEMA-PCASL technique combines PCASL with 3D segmented T1 weighted gradient echo sequence (3D-T1-TFE). PCASL preparation scheme with the Look-Locker sampling was used for spin labeling in this study (**Fig 1**). Seven phases of labeling and control images were acquired in an interleaved mode. Upon completion of two acquisitions, corresponding temporal phases with identical inversion delay were subtracted. MIPs were then created for each subtracted data set in three orthogonal directions. The timing information present in each acquisition was condensed into a single two-dimensional map of the estimated blood arrival time at each voxel.

Patient study: The study was approved by the Ethical Board of our hospital and informed consent was obtained from all patients (three men, five women; mean age, 36.5 years; age range 29–62 years). All examinations were performed on a Philips Achieva 3.0 Tesla scanner and equipped with a 32-element neuro-vascular coil. CINEMA-PCASL was implemented with the following parameters: FOV=220×200mm2, Matrix=224×162, 3D acquisition with 100×1mm slices, voxel size =1×1×1mm^3, flip angle=12°, TR=8.5ms, TE=4.2ms, SENSE factor=3.0, TI/ΔTI/final TI=300ms/300ms/2.0s, number of acquired time points=6. Labeling was performed by applying 425ms labeling duration, 200 to 2000 pulses with increments of 250ms produces 450, 700, 950, 1200, 1450, 1700 ms. A transverse labeling plane was positioned 9 cm below the imaging center. Total acquisition time is approximately 5 min. Two radiologists blinded to the CINEMA-PCASL findings at the initial reading evaluated the anatomical display of the AVM for the presence.

RESULTS AND DISCUSSION

CIEMA-PCASL and time-of-arrival map were successfully performed on 8 patients. Representative MIP images in the transverse, sagittal, and coronal orientations obtained in one patient with AVM are shown in **Fig 2**. In the images of the AVM patient, arterial blood filling starting from the Circle of Willis flowing through the major feeding arteries and into the nidus of the AVM can be clearly observed with a temporal resolution of 200 ms. Time-of-arrival map extracted from these data sets is demonstrated in **Fig 2**. The time-of-arrival maps present different filling time of every segment vessel in a single colorful image. The expected pattern of delayed transit to more distal vessels is apparent, along with earlier arrival in central portions of the larger vessels.

CONCLUSION

This study demonstrated the feasibility of the CINEMA-PCASL technique in evaluating the anatomic structure and dynamic filling of cerebral AVMs. Although further sequence optimization and clinical studies are required, this technique could play an important role in assessing structure and hemodynamics of intracranial arteries without using any contrast agents.
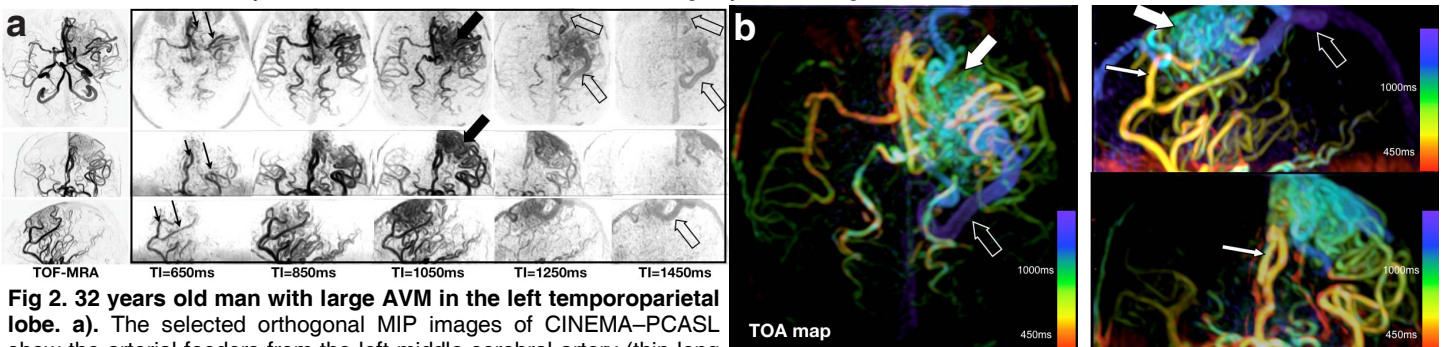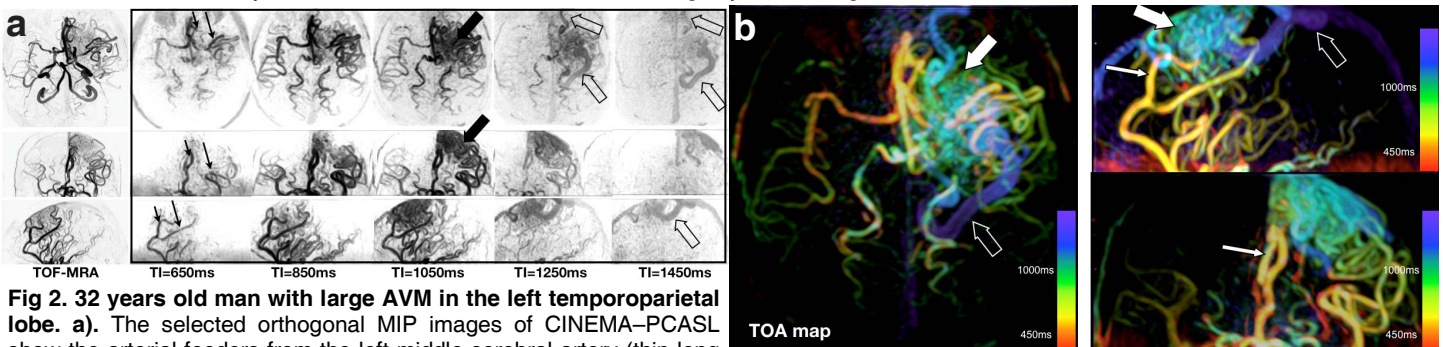

Fig 2. 32 years old man with large AVM in the left temporoparietal lobe. a). The selected orthogonal MIP images of CINEMA–PCASL show the arterial feeders from the left middle cerebral artery (thin long arrow), the anterior cerebral artery (thick long arrow), nidus (short arrow), and superficial venous drainage (open arrow).

b). Time-of-arrival color map is able to show differential filling rates for the arterial supply to AVMs; warm colors (red and yellow) indicate early arrival of blood, whereas cold colors (green and purple) indicate later arrival.

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