Non-Enhanced Extracranial Carotid MR Angiography Using Pseudocontinuous ASL: Comparison with Pulsed ASL and Clinical Feasibility at 1.5T

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Introduction: Extracranial carotid artery disease is a major cause of cerebral ischemia and infarction that is routinely assessed using nonenhanced time-of-flight and/or contrast-enhanced magnetic resonance angiography (MRA). Given known limitations of TOF MRA techniques, newer nonenhanced techniques such as pulsed arterial spin-labeling (PASL) offer potential benefits [1]. However, the signal-to-noise ratio (SNR) with PASL is impaired in several scenarios, such as when short repetition times are used to minimize the scan time, long labeling times are used to maximize visible vessel length, or when the imaging slab is positioned parallel to the vessel of interest so that it saturates the labeled region. A more recent labeling approach, pseudocontinuous arterial spin labeling (PCASL), has been reported to improve the SNR of cerebral perfusion imaging compared with PASL [2,3]. The purpose of this study was to investigate whether PCASL can improve the SNR of nonenhanced carotid MRA compared with pulsed methods.

Subjects and Methods: This study was approved by our Institutional Review Board and written informed consent was obtained from all participants. MR imaging was performed on a 1.5 T 32-channel MR Scanner (Avanto, Siemens Healthcare, Erlangen, Germany). Imaging of 7 healthy volunteers (5 male, 2 female; mean age 42.1 years) and 2 patients with documented internal carotid artery (ICA) disease on a prior duplex ultrasound (1 male, 1 female; mean age 63.0 years) was performed. PCASL and PASL carotid MRA were performed using a coronal balanced steady-state free precession (bSSFP) (TR/TE/flip = 3.1ms/1.3ms/90°) imaging slab centered at the carotid bifurcation and positioned at magnet isocenter. Radiofrequency (RF) labeling during PCASL was applied in an axial plane 5 cm below magnet isocenter according to the implementation of Dai et al. [3]: 500-μs-long sinc RF pulses; RF spacing of 1.5 ms; flip angle of 25°; maximum and average gradient strengths of 4.5mT/m and 0.45mT/m. A hyperbolic-secant adiabatic inversion labeling RF pulse (25cm thickness; centered 17.5cm below magnet isocenter) was used during PASL MRA. In healthy volunteers, PCASL and PASL were acquired using repetition and labeling times (TR/TI) of: 2.0s/1.7s, 2.0s/1.3s (acquisition time (TA)=164s), 2.0s/0.9s, 1.6s/0.9s (TA=131s), 1.2s/0.9s (TA=98s), and 1.6s/1.3s. Other common parameters were: receiver bandwidth of 977Hz/pixel, field of view of 256x320 mm, spatial resolution of 1x1mm, 64 1-mm-thick slices after interpolation, parallel imaging (GRAPPA) acceleration of 3. Signal measurements were obtained in the common carotid and extracranial internal carotid arteries, and compared using paired t tests.

Results: **Figure 1** shows angiograms demonstrating the improved signal obtained with PCASL over all the repetition and labeling times investigated. **Figure 2** summarizes the signal measurements made in the extracranial carotid arteries. Significantly larger arterial signal was obtained with PCASL (P < 0.05), with the largest signal gains (relative to PASL) observed as the labeling time approached the repetition time. Excellent correlation was observed between PCASL and with contrast-enhanced MRA (CE-MRA) in both patients. **Figure 3** shows a PCASL angiogram acquired in a patient with severe ICA stenosis (70-99%).
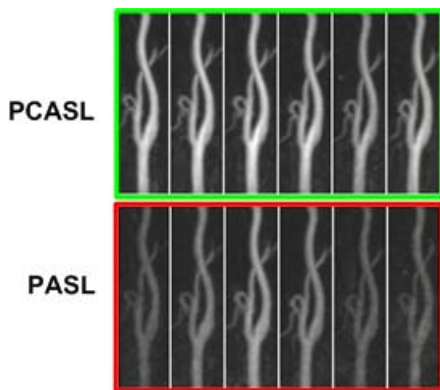

Figure 1. Montage of carotid angiograms obtained with PCASL (top panel) and PASL (bottom panel); from left, TR/TI=2.0/1.7s, 2.0/1.3s, 2.0/0.9s, 1.6/0.9s, 1.2/0.9s, 1.6/1.3s. Substantially improved signal is observed with PCASL.
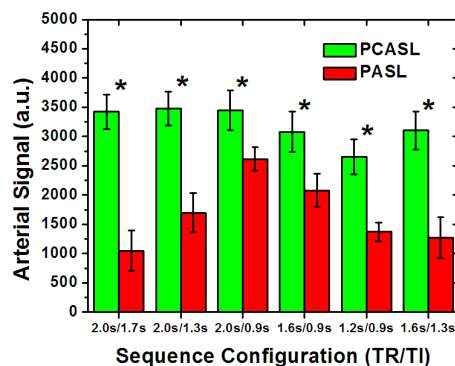

Figure 2. Bar plot summarizing the arterial signal measurements obtained in the volunteer studies. Significantly larger arterial signal was obtained with PCASL (*P < 0.05) over all repetition and labeling times investigated.
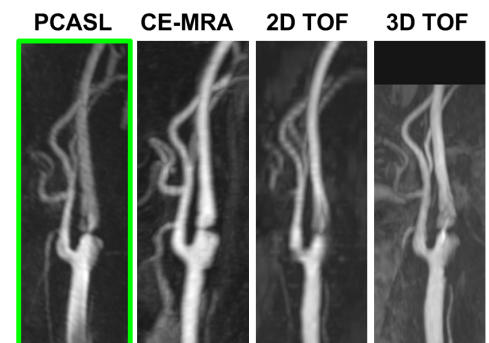

Figure 3. PCASL MR angiogram (left) obtained in a patient with severe ICA stenosis (TR/TI=1.4/1.15s). Excellent correlation is observed with CE-MRA.

Discussion and Conclusion: We found that pseudocontinuous ASL provides better performance than pulsed ASL for nonenhanced extracranial carotid MRA over a range of clinically useful repetition and labeling times. Furthermore, the clinical feasibility of the method was demonstrated in patients with documented carotid artery disease.

References: [1] Koktzoglou et al. MRM 2009; 61:117-124. [**2**] Wu et al. MRM 2007; 58:1020-1017. [**3**] Dai et al. MRM 2008; 60:1488-1497.