Hybridized arterial spin labeled MR angiography in the evaluation of carotid artery stenosis in patients with suspected stroke: Preliminary analysis and comparison to gadolinium-enhanced MR angiography

Kai Xu[1], LeRoy Stromberg[1], David Rusinak[1], Stephen Futterer[1], Shivraman Giri[1], James Carr[1], Robert Edelman[1], Ioannis Koktzoglou[2], and Jeremy Collins[1]
[1]Radiology, Northwestern University, Chicago, IL, United States, [2]Radiology, NorthShore University HealthSystem, Evanston, IL, United States

Purpose: First-pass gadolinium contrast-enhanced magnetic resonance angiography (CEMRA) is routinely used in the evaluation of carotid artery stenosis in cerebrovascular disease.[1] However, certain patient populations, most notably those with grade 4 or 5 renal insufficiency, cannot undergo gadolinium contrast-enhanced imaging due to the risk of nephrogenic systemic fibrosis.[2] Although vascular ultrasound is a first line modality in the assessment of carotid vascular disease, patient body habitus, operator dependence and a focus on physiological rather than anatomic characterization of carotid disease, highlights the need for a morphological imaging study to guide patient management. In this regard, novel MRA techniques that do not require gadolinium-based contrast agents would be of value if they provide similar diagnostic information to CEMRA. Hybridized arterial spin labeling (hASL), combining pseudocontinuous and pulsed labeling of arterial spins, has recently been optimized for non-enhanced imaging of the extracranial carotid arteries.[3] The purpose of this study was to assess the utility of hASL MRA to diagnose carotid artery stenosis in patients with a recent cerebrovascular event. We hypothesized that hASL MRA would produce angiographic images of similar quality and diagnostic confidence compared to the reference standard of first-pass CEMRA.

Methods: Twenty-four patients receiving clinically-indicated MRA examinations of the neck underwent imaging at 1.5 T (MAGNETOM Aera, Siemens AG, Healthcare Sector, Erlangen, Germany) or 3 T (MAGNETOM Skyra, Siemens AG). Patients were prospectively recruited under an IRB-approved protocol. Participants underwent the prototype non-contrast hASL MRA protocol and standard-of-care gadolinium CEMRA of the carotid arteries. hASL MRA was implemented using an undersampled 3D radial balanced steady-state free precession imaging readout with the following parameters: spatial resolution: 1.0 mm isotropic, receiver bandwidth: 558Hz, flip angle: 90°, acquisition time: 4 minutes. CEMRA was performed with injection of Gadavist (0.1 ml/kg, injection rate 2 cc/sec) with the following parameters: spatial resolution: 0.9 x 0.9 x 0.95 mm^3, sequence: spoiled gradient echo, band width: 488Hz, flip angle: 25°, slice thickness: 0.95mm, acquisition time: 18 seconds. Maximum intensity projection (MIP) reconstructions of the arterial anatomy encompassing the left and right common carotid arteries, carotid bulb, and proximal internal and external carotid arteries were generated for both techniques. MIP reconstructions were reviewed in separate sessions by a staff Neuroradiologist and scored on the basis of four criteria. Quality was scored from 1-4 for lumen delineation, intravascular signal homogeneity, venous signal/artifact, and diagnostic confidence, where 4 was excellent quality in all categories except venous signal/artifact, where 1 was excellent quality, as previously described.[4,5] The degree of stenosis at the left and right common carotid artery, carotid bulb, and proximal internal carotid artery was also assessed and categorized based on quartiles of stenosis (1 = <24%, 2 = 25-49%, 3 = 50-74%, 4 = 75-100%). Rating data was aggregated and differences between hASL MRA and gadolinium contrast-enhanced MRA were assessed using the student's t-test. Sensitivity and specificity of hASL in detecting any level of stenosis at the common carotid artery, carotid bulb, and proximal internal carotid artery, defined as a stenosis score greater than 1, was determined using CEMRA as the reference exam. If no stenosis was detected in any patient on CEMRA, sensitivity was not reported.

Results: hASL carotid acquisitions were successfully performed in all 24 patients. Paired carotid MIPs generated using hASL and CEMRA are shown in Figure 1. Qualitative scoring data are summarized in Figure 2. The quality of vascular lumen delineation, venous signal/artifact, and diagnostic confidence, were similar between hASL MRA and CEMRA, whereas intravascular signal homogeneity was superior with CEMRA than with hASL MRA (3.88 vs 3.46, $p < 0.01$). No stenosis was encountered in any patient at the common carotid on CEMRA or hASL MRA. Sensitivity at the proximal internal carotid was 100% for one patient (Figure 2b). Sensitivity at the carotid bulb was 100% for one patient. Specificity was 100% at all three locations.

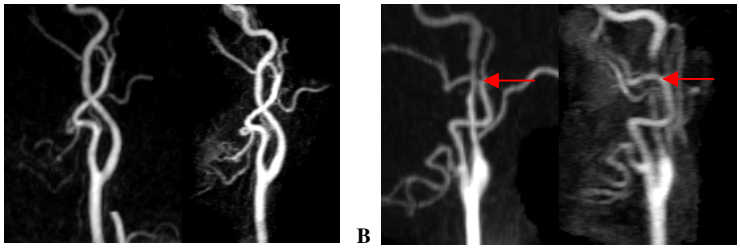

Figure 1 (above): A. MIPs of the carotid arteries from a single patient obtained using hASL MRA (left) and gadolinium CEMRA (right) showing normal vasculature. B. Internal carotid artery stenosis (arrows) secondary to acute dissection. Stenosis was graded as 25-49% on hASL (left) and 75-100% on gadolinium CEMRA (right).

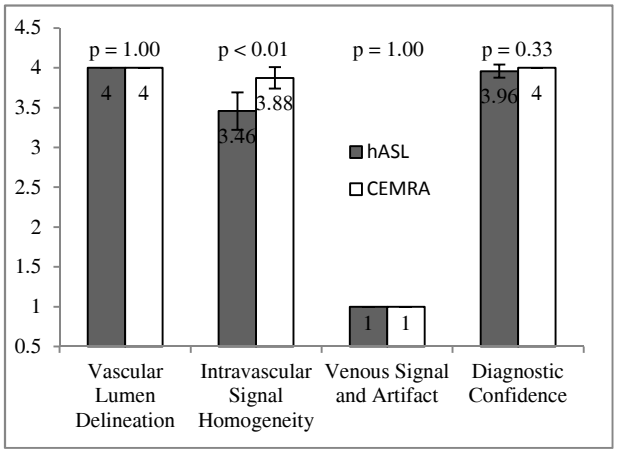

Figure 2 (right): Average quality rating scores for hASL and gadolinium CEMRA.

Discussion: Given the inherent limitations of carotid ultrasound and the current technical limitations of TOF MRA, there is a clinical need for a robust, non-contrast MRA alternative in patients with suspected carotid artery stenosis to help guide management in patients with renal insufficiency. Our preliminary results demonstrate agreement of hASL MRA compared to CEMRA to rule-out carotid artery stenosis. Diagnostic confidence, venous signal, and artifacts were similar between hASL MRA and CEMRA, with 100% of image quality scores in the "good" to "excellent" range (scores of 3 to 4).

Conclusion: hASL MRA is a promising non-contrast angiographic technique to rule-out carotid artery stenosis, particularly in patients with reduced renal function and limited imaging options.

References:[1] Cloft HJ et al. Magn Reson Imaging. 1996;14(6):593-600. [2] Kaewlai R et al. AJR Am J Roentgenol. 2012 Jul;199(1):W17-23. [3] Koktzoglou I et al. J Magn Reson Imaging (2014) doi: 10.1002/jmri.24640. [4] Kramer H et al. Eur Radiol (2011) 21:1667–1676. [5] Raoult H et al. Eur Radiol. 2013 Nov;23(11):3020-8.