MR Cerebral Angiography Using Arterial Spin Labeling for Dynamic Inflow Visualization and Vessel Selectivity

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Introduction: Digital subtraction X-ray angiography (DSA) is a widely used technique for the characterization of cerebral vessels. While MRI and CT can, in principle, provide angiographic information that could replace the riskier DSA study, which requires placement of a catheter for localized contrast injection and high doses of X-ray, these techniques typically lack the vessel selectivity and temporal resolution of DSA. Though arterial spin labeling MRI has primarily been used for perfusion imaging, recent developments including arterial selective imaging have made possible MR angiographic acquisitions with flexible labeling of arterial blood within feeding arterial vessels. Here we present the use of selective arterial spin labeling methods combined with balanced-SSFP acquisition to provide an MR angiographic exam more similar to DSA.

Methods: Imaging was performed on a 1.5 Tesla GE HDx system using the 8-channel head coil. For image acquisition, a 3D balanced SSFP (FIESTA) sequence was employed (TR: 3.6 ms; TE: 1.8 ms; FOV: 24 cm; matrix size: 256×128). This sequence gives excellent sensitivity for moving blood. After a preparation period, a linear ordered, half Fourier acquisition of one plane of k-space was acquired. In some acquisitions, slice encoding was performed after successive preparations to define 28-mm thick slices. The labeling and signal acquisition period was repeated every 6 s. Each acquisition of label and control images was 1 min 36 seconds. Angiograms were acquired both in the coronal and sagittal view. For dynamic angiograms, no slices encoding was performed and projection images were acquired with different labeling durations (up to 1.5 s in 150 ms increments). Each individual time resolved angiogram was acquired in 8 seconds.

Arterial spin labeling was performed with pulsed continuous arterial spin labeling (PCASL) (1) applied for 3 s prior to imaging ($B1_{ave}$ = 14 mG, G_{ave}= 0.07 G/cm, and G_{max}/G_{ave}= 10, Δt =1.5 ms). Presaturation and 3 selective inversion pulses were applied to achieve background suppression. Selective labeling of particular vessels was achieved using a previously reported technique (2) where an xy gradient added (G_{xy}=0.03 G/cm) is to the pCASL labeling and rotated between repetitions (G_{xy} rotates in 15^0 increment and B1 is amplitude modulated in a period of 192 TRs). Subtraction of label and control images was performed prior to magnitude reconstructions. Maximum intensity projections (MIPS) and inverted contrast were used to emphasize the similarity to DSA studies. The efficiency of selective angiograms relative to nonselective ones was evaluated in the coronal angiogram summation intensity projections.

Results and Discussions: The combination of ASL subtraction and background suppression eliminated virtually all background signal (Fig. 1). Major vessels were well visualized and even smaller vessels and possibly perfusion were apparent. The qualitative similarity to DSA is compelling. Selective angiograms demonstrated highly selective labeling of individual vessels. Extra-cranial signals not appearing in the selective angiogram indicated that the external carotid was not labeled while labeling the internal carotid artery. The efficiency of selective angiogram relative to the nonselective one was 83%, which was consistent with reported efficiency from single artery selective perfusion acquired with SSFSE (2). The contralateral carotid had 20% residual signal remaining in the selective angiogram due to the pulsatility effects still under study, but the brain area above the Circle of Willis had no visible vessel signal contamination. The signal-to-noise ratio (SNR) (3) for nonselective angiograms was 32. The dynamic angiograms demonstrated the feasibility of the technique to obtain dynamic inflow temporal resolution similar to that in DSA (Fig. 2). Of additional interest, 8-sec projection angiograms may be obtained (not shown) in rotated view angles giving 3-D visualization of torturous vessels. In summary, PCASL-based angiography with balanced SSFP acquisition is a promising method for rapid observation of collateral flow in diseased patients that can provide vessel-specific and time-resolved information, without the need for catheter injection.

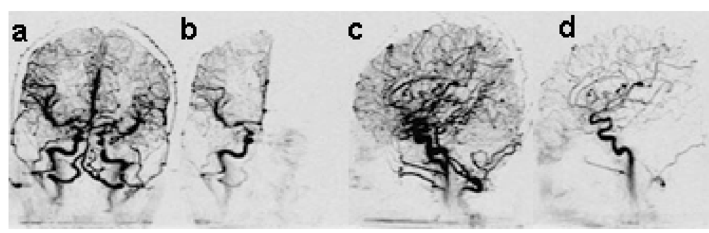

Figure 1.Cerebral angiogram maximum intensity projections (MIPs) from (a) nonselective ASL and (b) selective ASL in coronal acquisition and (c) nonselective ASL and (d) selective ASL on the right carotid artery in sagittal acquisition.

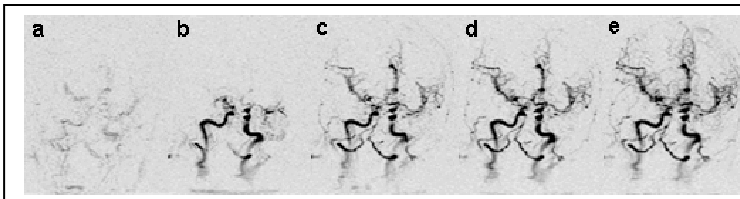

Figure 2. Coronal dynamic projection angiograms (8s per image) acquired at different time- points with labeling duration: (a) 300 ms, (b) 600 ms, (c) 900 ms, (d) 1200 ms and (e) 1500 ms.

References: 1. Dai et al, Magn Reson Med 2008; In Press. 2. Dai et al, ISMRM 2008, p. 31. 3. Constantinides et al, Magn Reson Med 1997;38:852-57.