

Superselective MR-angiography based on pseudo-continuous arterial spin labeling and first applications in AVM patients

M. Helle¹, S. Rüfer¹, W. Teeuwisse², O. Jansen¹, D. G. Norris^{3,4}, and M. van Osch²

¹Institute for Neuroradiology, Christian-Albrechts-Universität, UK-SH, Kiel, Germany, ²C.J. Gorter Center for high field MRI, Department of Radiology, Leiden University Medical Center, Leiden, Netherlands, ³Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, Nijmegen, Netherlands, ⁴Erwin L. Hahn Institute for Magnetic Resonance Imaging, Essen, Germany

INTRODUCTION: A detailed visualization of the cerebral vasculature is important in the diagnosis of many cerebrovascular diseases. Currently the intra-arterial digital subtraction angiography (DSA) is considered the gold standard for cerebral angiography. However, the procedure is invasive and it bears the risk of severe complications, such as the dissection of a vessel, beside the use of ionizing radiation and exogenous contrast agents. Recently, different variants of ASL angiography approaches have been developed [1,2]. However, the selectivity of existing methods is restricted to major brain feeding vessels like the internal carotid arteries (ICAs) and the basilar artery (BA). Moreover, most of these methods emphasize the similarity to DSA, thus only producing optimized coronal and sagittal projection images. In this study, we combined superselective ASL [3,4] with an optimized image acquisition which was applied in healthy volunteers as well as in AVM patients. This allows for selective labeling of single intracranial arteries even distal to the Circle of Willis. Furthermore, the acquired high-resolution 3D data allowed for reconstruction in multiple slices comparable to native time-of-flight (TOF) images as well as in different oriented maximum intensity projection images (MIPs) with sufficient spatial resolution.

MATERIALS AND METHODS: In a first study, selective labeling of major brain feeding arteries (ICAs, BA) was applied in 5 volunteers and qualitatively compared to a clinical TOF sequence. SNR and CNR analysis were performed in different sections of the internal, anterior, middle and posterior cerebral arteries (ICA, ACA, MCA, PCA). In a second study, 2 AVM patients underwent superselective ASL angiography. Labeling was performed on major brain feeding arteries and on individual AVM feeding vessels. Subsequently, the results were compared to DSA. In addition, perfusion-weighted superselective ASL [3] was applied to the same set of arteries to visualize associated flow territories and to identify en-passant feeding vessels. Prior to selective labeling, a non-selective ASL angiography scan with multiple labeling durations ranging from 100ms to 2500ms and with a single-slice acquisition was carried out in order to determine the optimal labeling duration for each volunteer regarding the individual inflow times of the blood. All measurements were performed on a clinical Philips 1.5T Achieva scanner using the body coil transmission and an 8-element phased-array head coil as receiving coil. Image acquisition in selective ASL angiography employed a segmented 3D balanced SSFP sequence with the following parameters: FOV 220x220x90 mm, voxel size 0.5x0.5x1.5 mm, SENSE factor 2, TFE factor 70, flip angle 90°, TR/TE 4.8/2.4, acquisition time ~ 4:30 min per vessel. Angiography images were obtained by complex subtraction of label and control images and combined into a color-encoded frame. MIP reconstructions were used to compare to DSA.

RESULTS AND DISCUSSION: Globally applied dynamic inflow angiograms revealed optimal labeling durations between 900msec and 1100msec in both healthy volunteers and AVM patients for the visualization of segments even those downstream of the 3rd branching level of the ACAs, MCAs and PCAs. When compared to TOF images, selective ASL angiography images did not show venous signal or signal of extracranial branches (fig. 1). SNR (fig. 2) and CNR values (not shown) acquired in the volunteer study showed significant differences between labeled and non-labeled vessels. Due to the increased selectivity needed for the labeling of vertebral arteries and the basilar artery the labeling efficiency is reduced in these vessels resulting in decreased SNRs and CNRs in the PCAs. However, effects on the image quality seem negligible. In addition, superselective ASL angiography was successfully applied in both AVM patients and showed good agreement compared to DSA. From DSA images alone an exact anatomical allocation is problematic especially when the DSA images are acquired in different orientations (fig. 3, 4). Superselective ASL angiography made it possible to label different vessels but to acquire the data in unchanged orientation. Thereby, in color-encoded slices and MIPs it was possible to identify different compartments of an AVM which were supplied by a single feeder or in which mixing of blood of two or more feeders occurred which was only barely visible in DSA images. Disadvantages of this technique are the single time-point acquisition for high-resolution images and its inherent sensitivity to motion, e.g. eye movement (fig.3). However, with dynamic inflow angiograms it is possible to determine the optimal labeling duration for the final image acquisition. This approach for selective ASL angiography not only mimics DSA but also combines advantages of superselective labeling and high resolution 3D image acquisition. In combination with superselective ASL perfusion imaging (fig.5) this approach may serve as an important clinical tool, especially in the diagnosis of AVM patients.

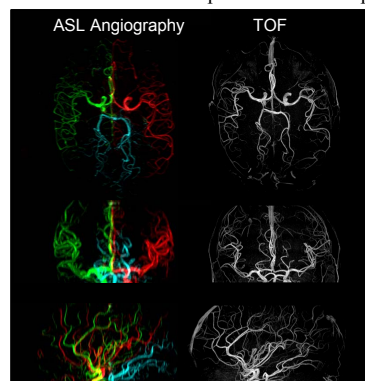


Fig.1: Color-encoded selective ASL angiography MIPs (ICA right, ICA left, BA) in a normal volunteer did not show venous signal or signal of extracranial branches compared to TOF MIPs.

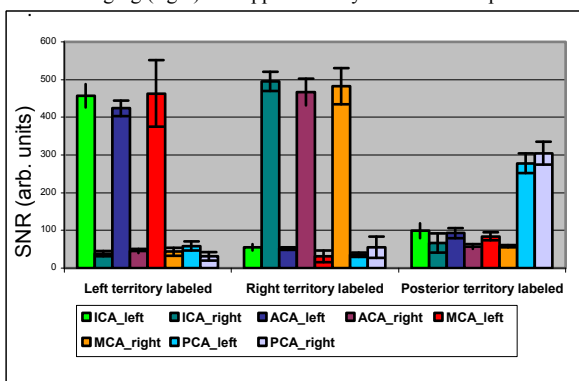


Fig.2: SNR values measured in different arterial segments showed significant differences between labeled and non-labeled vessels. Due to an increased selectivity needed for the labeling of vertebral arteries and the basilar artery, respectively, the labeling efficiency is reduced in these vessels resulting in decreased SNRs in the PCAs.

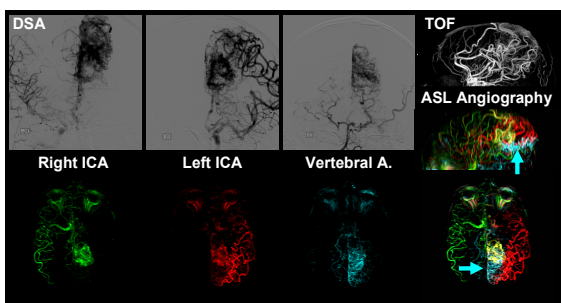


Fig.3: Color-encoded ASL angiography MIPs of an AVM patient compared to DSA and TOF MIP. Merged MIPs revealed different compartments of the AVM supplied by a single feeder (arrows) or by multiple feeders (mixed color yellow) which is not visible in TOF images and only barely visible in DSA.

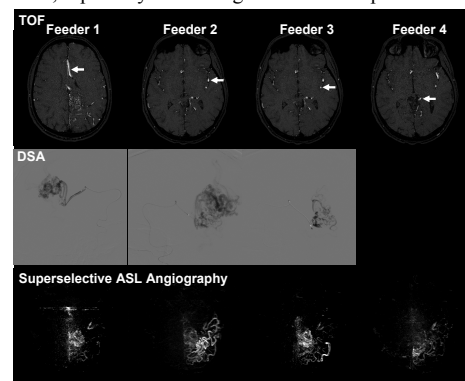


Fig.4: MIPs of superselectively labeled feeding vessels of the same AVM patient as in fig.3 compared to corresponding DSA images. DSA could only be applied to 3 of the 4 feeders. The extent to which a single feeder contributes to different compartments of the AVM could be visualized which was only barely visible in DSA images especially due to different orientations for the data acquisition in DSA.

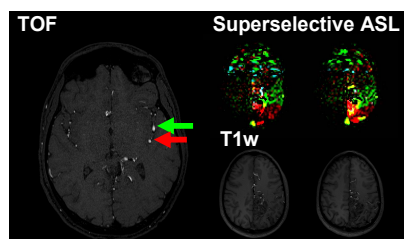


Fig.5: Representative superselective ASL perfusion images of the same AVM patient as in fig.3 and 4. Two feeding vessels of the AVM were identified as an en-passant feeder; the other feeding vessels only supplied the AVM.

REF.: [1] Robson et al, Radiology 2010;257:507-15; [2] Okell et al, MRM 2010;64:430-8; [3] Helle et al, MRM 2010;64:777-86; [4] Helle et al, ISMRM 2010: #523