A New Method for Selective Dynamic MRI Angiography using Arterial Spin Labeling

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Introduction Selective arterial angiographic information is conventionally achieved using x-ray based digital subtraction angiography (DSA), in which radio-opaque contrast agent is injected under x-ray guidance via a catheter. These x-ray DSA methods are invasive, labor intensive, and carry risks to the patient, most significantly a risk of stroke. For these reasons the valuable dynamic flow information that x-ray DSA can provide is often limited to a single examination, and to major centers with neurosurgical back-up where clinical risk is outweighed by the potential patient benefit. Here we demonstrate a non-invasive method, based on selective arterial spin labeling (ASL) MRI, that can be used multiple times during disease assessment or treatment, and in a wider range of patients.

Theory The use of ASL for angiographic contrast, in which blood proximal to the slice(s) of interest is inverted and compared with an image where the blood signal is not inverted, dates back to the work of Edelman *et al*. [1]. Dynamic ASL angiography enables cine readout of the tagged blood as it moves away from the tag location. More recently, van Osch *et al*. [2] have attempted to generate selective ASL angiograms by using obliquely orientated ASL slabs that pass through (ideally) only one feeding artery, thus avoiding labeling nearby vessels. This approach, however, relies on favorable vascular geometry, cannot easily be used above the level of the Circle of Willis, and leads to obscuring artifacts in the superior imaging slices. Here we adapt the selective arterial territory perfusion mapping technique developed by Wong [3] to the acquisition of dynamic angiography. This involves combining a pseudo-continuous ASL (PCASL) labeling approach [4] with a transverse blipped gradient phase encoding and RF phase cycling scheme in order to specifically tag a bolus of blood spins that pass through a specific point in the desired feeding artery. By using combinations of encoding strategy it is possible to selectively label a number of different feeding vessels, either below or above the Circle of Willis, and to obtain selective angiograms for each.

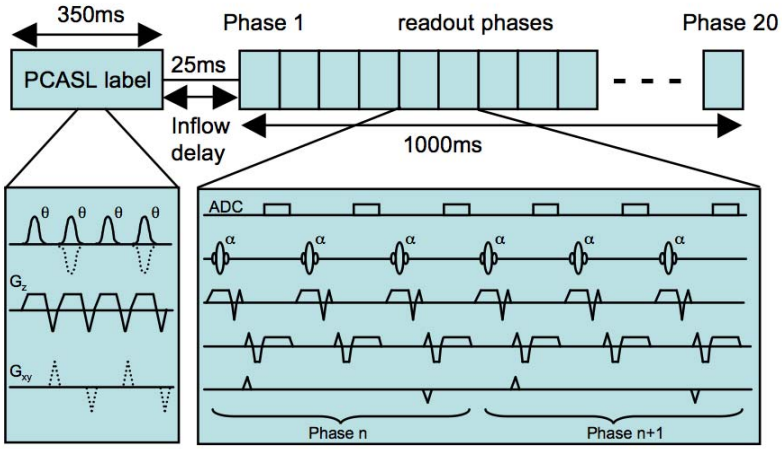

Fig. 1: Selective dynamic angiography pulse sequence (phase cycling shown dashed).

Methods and Results The pulse sequence used for selective ASL dynamic angiography is shown in Fig. 1. It consists of a 350ms period of PCASL labeling to achieve efficient inversion of arterial spins at a location in the neck. Combinations of transverse labeling 'blips' were calculated such that either the left or right internal carotid artery was tagged (with the contra-lateral artery being unlabeled), or such that the vertebral or carotid supplies were tagged (with the carotid or vertebral supplies being unlabeled, respectively). Two further conditions were acquired in which either no vessels were tagged (unlabeled) or all vessels were tagged. On each occasion the PCASL tagging was followed by a low-flip-angle gradient-echo readout module [5,6]. Scanning was performed on a Siemens 3T TIM Trio, using a 12-channel head receive coil and body transmit. The parameters for the PCASL module were as follows: Gaussian RF pulse; θ=20° flip angle; duration 600μs, inter-pulse interval 960μs; mean gradient of 0.8mT/m. Following a 25ms inflow delay, 20 time intervals, separated by 55ms, were read out in a single 5cm slab centered on the Circle of Willis (flow-compensated FLASH, TR=18ms, TE=3.74ms, flip angle (α)=10°, FOV=205×170mm, 192x156 matrix, 3 segments). The total imaging time was 10 minutes. Data were subsequently processed using the matrix inversion method of Wong [3] to separate the contributions from the three feeding arteries of (i) left internal carotid artery; (ii) right internal carotid artery; and (iii) basilar artery. Fig. 2 shows results in a representative subject, where the separately identified selective labels, calculated by matrix inversion of the raw data, have been color coded in red (right ICA), green (left ICA) and blue (basilar). In this healthy subject with intact Circle of Willis the expected branching patterns are seen, with filling of the ipsilateral middle and anterior cerebral arteries from its respective internal carotid, and bilateral posterior cerebral artery filling from the posterior circulation. For this image the time course data has been collapsed using a temporal maximum intensity projection, but dynamic data (not shown) can also be displayed showing each vessel's tagged bolus passing through the vasculature.

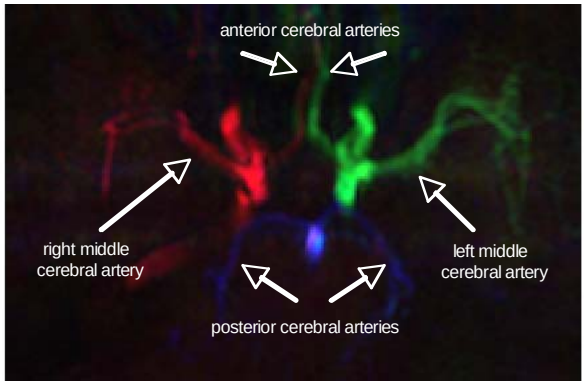

Fig. 2: Axial slab showing separation of left, right and basilar arterial branching vessels with selective ASL dynamic angiography.

Discussion and Conclusion Here we demonstrate the first implementation of a non-invasive selective dynamic angiography MRI pulse sequence, with ability to separately map the arterial branches of major feeding vessels, in a manner analogous to invasive intra-arterial x-ray DSA. The method should have application in a number of clinical disorders, including assessment of carotid and vertebral atherosclerosis, stroke, and arterio-venous malformations. In addition to static angiograms, the data can also be used to visualize dynamic passage of the tagged bolus as it passes through the cerebral vasculature. The technique could also be applied to other body organs and to more distal vessels where selective labeling can be performed without contamination from adjacent vessels.

References [1] Edelman *et al*. Magn Reson Med 31:233-8 (1994); [2] van Osch *et al*. Med Image Anal 10:59-70 (2006); [3] Wong, MRM 58:1086-91 (2007); [4] Garcia *et al*. Proc ISMRM 13:37 (2005); [5] Günther *et al*. MRM 46:974-84 (2001); [6] Günther *et al*. Proc ISMRM 10:1100 (2002).