Single Pair Arterial Spin Labeling Imaging

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Introduction Arterial spin labelling (ASL) is a powerful non-invasive MR technique to examine cerebral blood flow (CBF), in which the perfusion weighted signal comes from the difference between a flow sensitive (label) image and non-sensitive (control) image. Due to the small amplitude of this difference, a large number of such pairs have to be acquired to derive a sufficient level of Contrast to Noise Ratio (CNR) based on signal averaging. This results in prolonged experimental duration making data susceptible to physiological noise and importantly for clinical applications may proves to be unfeasible in challenging patients such those with as Alzheimer's and Parkinson's diseases. Recently efforts have been made to accelerate perfusion acquisition [1]. Two major sources of signal loss are T1 relaxation of tagged magnetization during transit between the labelling zone and imaging slice and T2* relaxation during imaging readout. In multislice acquisitions the labelling zone can be a significant distance from central slices within the imaging pack. Single slice imaging with a tightly restricted inversion slab reduces the dead zone between imaging slice and tagging zone and may reduce the tagged signal lose due to transit delay. In this work, we present a FAIR [2] based technique to accelerate perfusion image acquisition through a combination of single slice imaging and spiral readout to mininize TE.

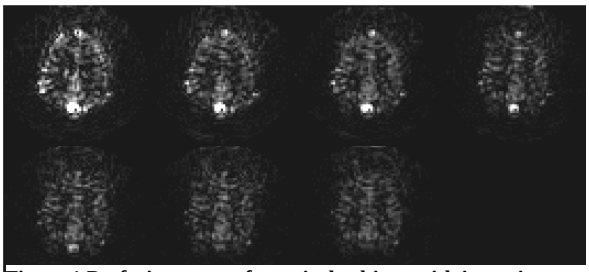

Figure 1 Perfusion maps of a typical subject, with inversion width , from left to right, 12, 24, 36, 48 mm (top), and 60, 72, 84 mm (bottom), showing a visible reduction in contrast with the increasing inversion slab.

Methods A FAIR sequence was implemented on a 3T whole body system (Achieva, Philips Medical System, Netherlands) with single shot spiral readout (TE/TR=11.13/4000 ms, 6mm thick, 64×64 matrix size, 4x4 mm^2 resolution and an acquisition window of 20 ms). Experiments were conducted using the body coil for transmission and an 8 channel head coil as receiver. For each scan, 16 pairs of images were acquired with bulk flow suppression gradient (10 ms bipolar gradient at 14 mT/m) on each axis. For *in-vivo* studies, written consent was attained priory to scanning, and the study was approved by local ethics committee.

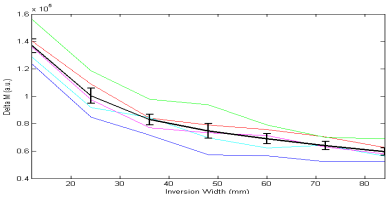

Figure 2 Mean gray matter ΔM versus inversion slab width for each subject (colors). mean±SE plotted in black

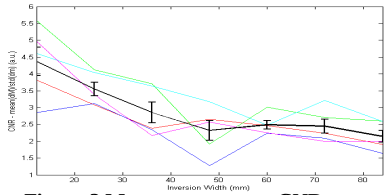

Figure 3 Mean gray matter CNR versus inversion width for each subject (colors). mean±SE plotted in black.

Experiments: (i). To examine the effect of the distance between tag and imaging zones on CNR five healthy subjects aged between 24 and 38 were scanned with the inversion slab width set to 12, 24, 36, 48, 60, 72 and 84 mm, co-centred with the imaging slice and at inflow time of 1700 ms. A spherical phantom containing agar gel (T_1=1190 ms, T_2=100 ms) was also scanned using the same protocol to ensure no subtraction artefacts were created by varying inversion width.
Experiments: (ii). To examine the CNR efficiency of a single slice acquisition a healthy male subject (age 33) was scanned with inversion width at 12 mm and inflow time set to 1000, 1150, 1300, 1450, 1600, 1750, 1900 ms.

Results The perfusion maps of a typical subject at the range of inversion slab widths are shown in Fig 1, and the quantification within gray matter for all subjects is shown in Fig 2. It is clear that increasing inversion width leads to significantly reduced CNR. At larger inversion widths the difference resulting from changing inversion width is less prominent due to vascular dispersion effects. The relationship between CNR with inversion slab width is plotted in Fig 3, demonstrating an ~1.8 times increase in CNR at the narrowest inversion width. It is worth noting that the noise here is calculated in the time-series fashion, which indicates that physiological noise is also contained in this calculation. Perfusion maps of the subject acquired using the single slice method at a range of inflow times are shown in Fig 4, and quantification within gray matter is shown in Fig 5. Using the gain in sensitivity provided by the single slice spiral readout approach, data from single pair subtractions in the 5 subjects are shown in Fig 6.

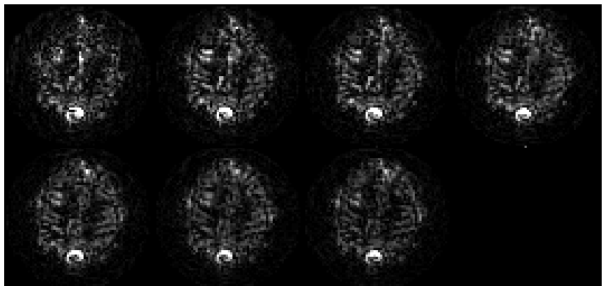

Figure 4 Perfusion maps of a subject scanned with inflow times, from (top) 1000, 1150, 1300, 1450 ms, (bottom) 1600, 1750, 1900 ms

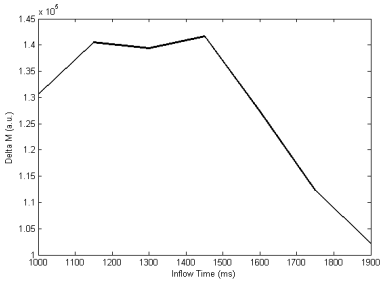

Figure 5 Mean gray matter ΔM versus inflow time.

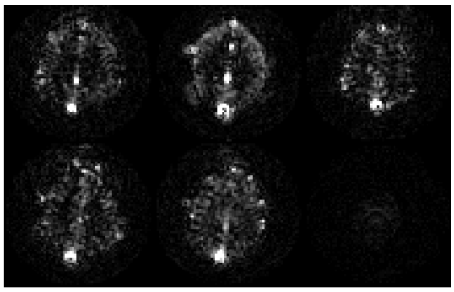

Figure 6 Perfusion maps of single pair acquisition of 5 subjects and a phantom

Discussion It was demonstrated that a combination of spiral acquisition and single slice imaging with tightly coupled inversion slab can enhance the CNR of perfusion maps by a factor of ~1.8. The use of spiral readout in place of EPI reduces TE by ~20ms leading to a SNR gain of ~1.5 times (assuming T2* of 50ms). Total gain in CNR versus a conventional multislice preparation with EPI readout is then ~2.7 allowing significant reduction in acquisition time at the expense of limited brain coverage. Using this approach a single pair of such acquisition can achieve perfusion maps of reasonable quality.

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References [1] Fernández-Seara MA, Edlow BL, Hoang A, Wang J, Feinberg DA, Detre JA., Minimizing acquisition time of arterial spin labeling at 3T. MRM 2008;59(6):1467-71 [2] Kim SG, Quantification of relative cerebral blood flow change by flow-sensitive inversion recovery (FAIR) technique: application to functional mapping, MRM 1995; 34(3): 293-301