Multi-Slice Look-Locker FAIR for Hepatic Arterial Spin Labelling

Rajiv Ramasawmy *[1,2], Adrienne Campbell-Washburn *[1], Sean Peter Johnson[2], Jack Wells[1], Rosamund Barbara Pedley[2], Simon Walker-Samuel †[1], and Mark F Lythgoe †[1]

[1]*Centre for Advanced Biomedical Imaging, University College London, London, Greater London, United Kingdom,* [2]*Cancer Institute, University College London, London, Greater London, United Kingdom*

Target audience: This abstract will be of interest to those interested in arterial spin labelling, liver perfusion or liver disease.

Purpose: Arterial spin labelling (ASL) is used in the brain [1], heart [2] and kidney [3] to measure perfusion but has not yet found extensive utility in the liver, due to its dual vascular supply and susceptibility to respiratory motion. Non-invasive liver perfusion measurements could monitor hepatic disease progression and drug efficacy in pre-clinical models of cirrhosis [4] and tumour metastasis [5]. Previous work demonstrated single-slice Look-Locker Flow-Sensitive Alternating Inversion Recovery (FAIR) hepatic ASL measurements [6]; however a multi-slice perfusion sequence would increase efficiency of whole liver coverage when imaging multiple metastases and gross liver dysfunction. In this study we demonstrate the use of a multi-slice Look-Locker FAIR ASL and compare it to equivalent single-slice perfusion data.

Methods: *ASL acquisition*: Single slice perfusion measurements were obtained using a respiratory-triggered inversion, segmented FAIR Look-Locker ASL sequence with a spoiled gradient-echo readout [6]. The multi-slice sequence was adapted from the single-slice technique with additional segmented acquisition pulses for each slice within the Look-Locker train [7]. Multi-slice sequence parameters were: FOV 30 x 30 mm^2; matrix size 128 x 128; 3x1 mm slices with 0.2 mm gap, TE 1.18 ms; TI 110 ms; TR_{RF} 2.3 ms; α_{LL}=8°; TR_I 13 s; 50 inversion recovery readouts, 4 lines per segmented acquisition, 15 minute acquisition time. For both single- and multi-slice acquisitions, a localised 6 mm slice selective inversion centred on the middle slice was followed by a global inversion. Scans were performed on a 9.4T Agilent VNMRS 20 cm horizontal-bore system, using a 39 mm birdcage coil. Inversions were triggered at the end of the inspiration phase using respiratory gating apparatus (SA Instruments, US).
In vivo measurements: Three mice were anaesthetised using 1.5% isoflurane in 100% O_2 and positioned in the centre of the magnet. Core body temperature was monitored and maintained using a warm air blower. Respiratory-gated fast spin echo images were used to define suitable axial imaging slices within the liver.
Post-processing: Perfusion maps were calculated using the model as described by Belle *et al* [2]. A blood-tissue partition coefficient of 0.95 ml/g was taken from ^{85}Kr gas clearance measurements [8]. The liver capillary blood T1 was assumed to be 1900 ms, from previous T1 measurements of the ventricular blood pool in the mouse heart [9]. Perfusion to the liver is assumed to be delivered from both the arterial and venous systems.

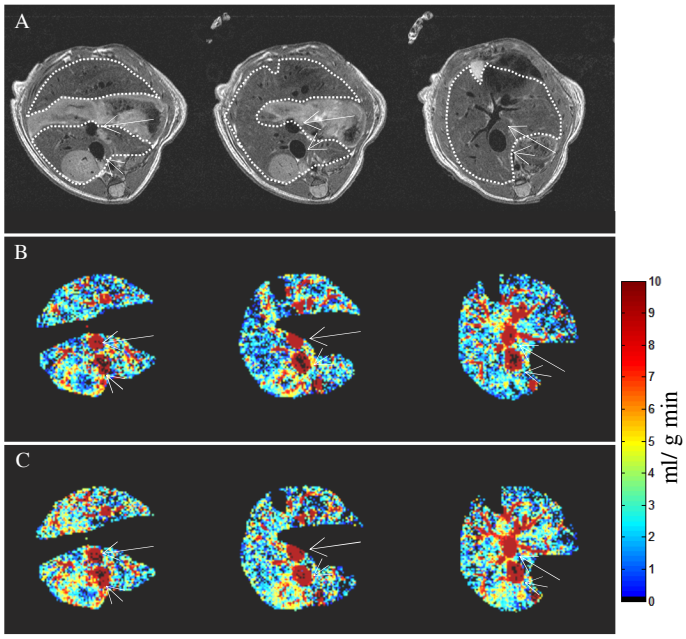

Figure 1: Three T2-weighted, fast spin echo images of a liver at the different slice positions with the liver ROI outlined (Row A). Corresponding single-slice perfusion maps (Row B) and multi-slice perfusion maps (Row C). Visual inspection indicates good correlation between the two techniques; high flow can be seen at major blood vessels such as the portal vein (long arrow) and inferior vena cava (short arrow).

Results: Fig. 1 shows three slices through a murine liver: for each column there is an anatomical T2-weighted image (Row A) of the liver above its associated single slice (Row B) and multi-slice perfusion map (Row C). On the anatomical images, the stomach and blood vessels appear hypo-intense compared to liver tissue. The major vessels can be visualised in Fig. 1B & 1C due to a large but non-physiological perfusion signal. The multi-slice perfusion maps (mean perfusion p_{MS} = 2.1 ± 0.8 ml/g min) compares well with the single slice (mean perfusion p_{SS} = 1.9 ± 0.7 ml/g min) though Bland-Altman analysis suggests a slight overestimation in the multi-slice with a mean difference of 0.25 ml/g min. Our multi-slice liver perfusion values are comparable with ^{85}Kr gas clearance measurements [8].

Discussion & Conclusions: Arterial spin labelling has been principally used for measuring brain perfusion [2], with more recent application to cardiac [3] and renal [4] imaging. We have previously shown the feasibility of localised liver perfusion measurements using FAIR-ASL [6], an application that has not been extensively reported in the literature, and here demonstrate an improvement to this technique with a multi-slice adaptation. For these data the multi-slice sequence offers a threefold increase in time efficiency for the same liver coverage as the sequence takes the same amount of time as a single slice acquisition (less than 15 minutes); the sequence could easily be adapted to cover more slices. The slight perfusion overestimation measured could be corrected with a more appropriate quantification method which accounts for inflowing blood magnetisation [7]. The perfusion maps generated are from a mixture of both the arterial and portal systems; a pseudo-continuous ASL method could be implemented to evaluate their respective contributions. Using this sequence, we aim to investigate perfusion changes in colorectal cancer metastasis induced by novel anti-cancer therapies. Furthermore, brain and kidney FAIR ASL is commonplace in clinical scanners, and given the non-invasive nature of the technique, we anticipate that translating hepatic multi-slice Look-Locker FAIR ASL into a clinical setting would be straightforward.

**Joint First Authors* *†Joint Senior Authors*

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