Arterial Spin Labelling Characterisation of Renal Medullary Perfusion

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INTRODUCTION: Renal function involves flow between the separate cortical and medullary structures of the kidney. Measurements of the perfusion to both tissues could be of importance in understanding renal physiology and disease. Arterial Spin Labelling (ASL) shows promise as a quantitative, non-invasive probe of renal blood flow (1). Much attention has focused on evaluation of the higher perfusion signal in the renal cortex. For many renal pathologies however, ischemic or hypoxic damage to the outer medulla is most prominent (2). Unlike the inner medulla, where perfusion may well be too low for accurate measurement, the outer medulla normally has a blood flow estimated by different techniques at between 25-60% of the cortex (2, 3). Two factors may complicate ASL measurement of outer medullary blood flow, however. One is simple partial volume averaging of the brighter renal cortex voxels and the nearby outer medulla. This may be addressed with higher resolution imaging. The second complication relates to the flow geometry of the kidney. Flow to the outer medulla first passes through the cortex, which is known to hinder measurement of blood flow using microspheres (4). Here also, much of the arterial water labelled by ASL may exchange with the tissue. To investigate the effect of these factors on the perfusion measurement, high resolution ASL was performed both with pCASL labelling of the aorta outside the kidney and thin slice FAIR labelling, which labels flow between neighbouring sections of kidney.

METHODS: Thin 2.6-mm slices were acquired in the axial orientation to minimise partial volume effects from mixing cortical and medullary perfusion signals. High in-plane resolution of 2.5-mm was used with 128x128 matrix size over a 32-cm FOV. Image acquisition used a 2D single-shot FSE sequence to freeze motion artefacts; a 9/16 partial Fourier centre-out scheme of 130 deg pulses, stabilised by 3 extra pulses was used. Imaging times of 25 min (128 label-control pairs) were used to increase SNR. Pulsed-continuous labelling (pCASL) used 1.5 sec labelling in the descending aorta with a 1.5-sec post-labelling delay (5). FAIR utilised a FOCI inversion pulse 2.4 sec prior to imaging. Both labelling schemes employed background suppression inversion pulses. Mean perfusion difference signal in ROIs placed on the cortex and medulla were compared to regions of thermal noise to test the statistical significance (two-tailed Student's t-test) of the measured perfusion signal. Quantitative values were then obtained (6) using an Mo image, acquired with the same sequence without labelling or background suppression pulses, and T1 values for cortex and medulla of 970 msec and 1410 msec (7).

RESULTS: Figure 1 shows the perfusion difference images with pCASL and FAIR labelling. Quantitative images in Fig. 2 show the regions of the cortex and medulla used for ROI measurements (confirmed by comparison to a T1-w SPGR anatomical image). Mean perfusion difference signals, averaged over 8 ROIs of medulla and 6 of cortex were significantly greater with FAIR labelling than pCASL in both tissues; p=0.03 (medulla), 0.01 (cortex). Mean medulla signal was significantly greater than the background noise with FAIR labelling, p=0.001 but not with pCASL, p=0.06. Average quantitative values of flow in the medullary / cortical tissues were 131 / 405 (FAIR), and 62 / 324 mL/100g/min (pCASL). The ratio of medullary to cortical perfusion was 28 and 17% for FAIR and pCASL labelling.

DISCUSSION: Perfusion signal seen in the medulla is significant compared to background thermal noise; greater statistical significance is seen with FAIR labelling than with pCASL. This is consistent with the labelling methodology and the serial structure of the vasculature, first flowing through the cortex and then the medulla. Qualitative assessment of the medullary ROIs indicate that much of the perfusion is present in the outer medullary layer with little signal observed in the inner medulla. With FAIR preparation, there is substantial vascular signal; furthermore, the desire to label close to the imaging slice to label slow flow from the cortical to medullary vascular beds leads to a higher potential for motion to produce artefactual signal, both of which must be separated from the perfusion signal. However, FAIR labelling, with long acquisition times to increase SNR, shows the potential to measure perfusion in the cortical and medullary tissues of the kidney.

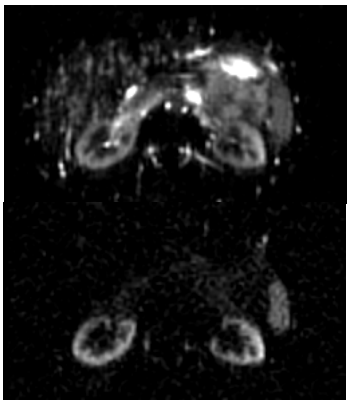

Fig 1. Perfusion difference images; FAIR labelling (top) and pCASL (bottom).

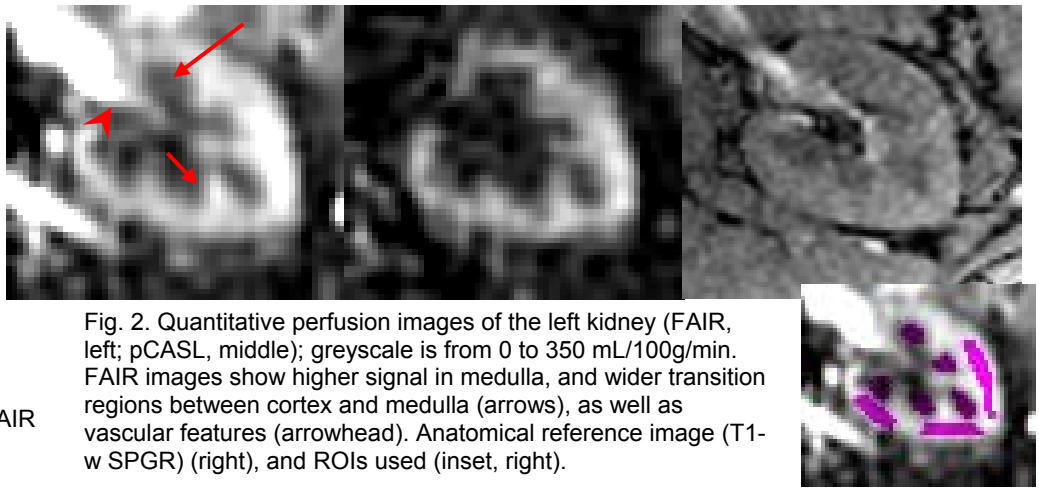

Fig. 2. Quantitative perfusion images of the left kidney (FAIR, left; pCASL, middle); greyscale is from 0 to 350 mL/100g/min. FAIR images show higher signal in medulla, and wider transition regions between cortex and medulla (arrows), as well as vascular features (arrowhead). Anatomical reference image (T1-w SPGR) (right), and ROIs used (inset, right).

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