

High Resolution Respiratory Triggered Multiphase TrueFISP ASL

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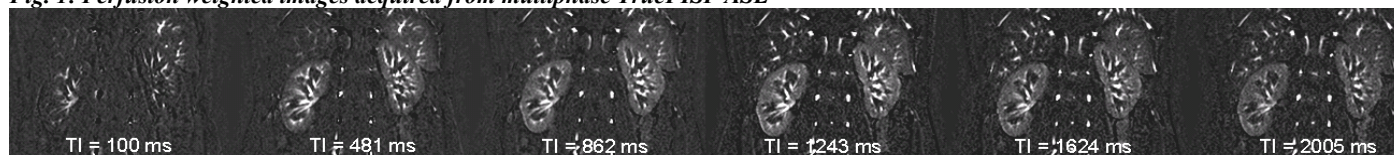
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Introduction: Arterial spin labelling (ASL) allows the assessment of renal perfusion without the need for contrast agent [1]. The renal circulation comprises cortical interlobar, arcuate and interlobular arteries supplying glomeruli and peritubular capillaries providing medullary perfusion. Techniques to probe this vascular network at high resolution will provide information on renal physiology and can be used to study the pathological mechanisms which lead to chronic kidney disease. ASL is however a subtraction technique, and so is highly sensitive to respiratory induced movement of the kidneys and further, partial voluming of parenchyma with arteries can limit accurate perfusion assessment. Recently multiphase (Look-Locker-like readout) ASL using the rapid acquisition of images at multiple delay times (T_I) following labelling has been implemented in the kidney [2,3], allowing the assessment of transit delay (which itself may be prolonged in kidney disease) and improving perfusion quantification. However, to date this method has been limited to relatively coarse spatial resolution with data being collected during repeated breath holds [2]. Here we introduce a respiratory triggered variant of the multiphase acquisition and use this to collect high resolution multiphase data during free breathing to assess the heterogeneity of transit time and perfusion across the kidney.

Methods: The study was approved by the local Ethics Committee. A single subject was scanned on a 1.5 T Philips Achieva whole body scanner with a 16-element SENSE torso coil. Multiphase data (288 x 300 mm FOV, 1.5 x 1.5 mm² voxel, 3 mm slice thickness) was collected with a TrueFISP readout (TE/TR 2.1/4.1 ms, SENSE 2, flip angle 60°, low-high acquisition, and half-Fourier acquisition, shot duration 316 ms). The multiphase data was collected whilst free breathing by introducing a respiratory trigger delay of 1000 ms prior to the ASL labelling, labelling was then followed by multiphase sampling with an initial delay (T_I) of 100 ms, and subsequent readout spacing (T_A) of 381 ms with 6 readout phases being acquired (to span a post-label delay of 100 - 2005 ms). In this way the ASL data was collected in the 'flat period' of the respiratory cycle between expiration and inspiration. Following this multiphase data acquisition, a high resolution respiratory triggered single phase ASL (5 slices) data set was acquired at $T_I = 1100$ ms (again in 'flat period' of respiratory trace). For both multiphase and single phase ASL acquisition, 100 ASL pairs were collected in ~ 15 mins. Following ASL acquisition a base M_0 dataset was acquired with long TR.

Data Analysis: Each tag and control image pair in the time-series was first realigned to the M_0 base image, by applying the FLIRT automated linear (affine) registration technique (FSL, fMRIB), to overcome any small degree of motion that was apparent. Images were then subtracted in a pair-wise manner on a voxel-by-voxel basis and averaged to form a perfusion weighted (PW) image for each phase. An average of the multiphase control images was then formed, and fitted to a 2 parameter model to generate a T_1 and M_0 map. The multiphase PW difference signals were then fitted on a voxel-by-voxel basis, using the M_0 and T_1 maps and a binary kidney mask, to a 2 parameter model for transit time and perfusion [4] using a Powell minimization. The T_1 map was used to segment the cortex of the kidney to assess the mean perfusion and transit time, neglecting the vessels.

Fig. 1: Perfusion weighted images acquired from multiphase TrueFISP ASL



Results and Discussion: Fig. 1 shows the PW data from the multiphase TrueFISP ASL acquisition with inflow of labelled blood seen arriving in the renal artery and interlobar/arcuate arteries before perfusing the cortex. Fig. 2A shows the T_1 map calculated from the control ASL data clearly discriminating the cortex and medulla, and the cortex mask (Fig. 2B) segmented by thresholding this map. Fig. 3 shows the transit time (in ms) and perfusion (in ml/100g/min) map calculated from the multiphase PW images. The PW images depict early inflow in the arteries as shown by short transit times, labelled blood then perfuses the inner cortex before the outer cortex and outer medulla. In the renal cortex ROI the mean (\pm stdev.) transit time was 472 ± 178 ms, reflecting the transit delay across the cortex, and the mean (\pm stdev.) perfusion was 329 ± 85 ml/100g/min, the standard deviation indicative of the variation in perfusion within the cortex in the high resolution data. Figure 4 shows the single phase PW data from the corresponding slice (A) and an additional slice shown (B) to highlight the clear differentiation of the progressively branching arteries which can be visualised in the high resolution respiratory-triggered data.

Conclusions: Using respiratory triggered multiphase ASL data acquisition it is possible to collect high resolution perfusion and transit time maps of the kidney, allowing the assessment of heterogeneity across the kidney. These techniques will be applied to the study of perfusion in the assessment of renal disease.

References: [1] P Martirosian et al. MRM 2004; 51(2): 353-361, [2] CL Hoad et al. Proc. ISMRM 2010 P327, [3] NS Artz et al. Proc. ISMRM 2010 P2680, [4] ST Francis et al. MRM. 2008; 59(2): 316-25.

Fig. 2: (A) Calculated T_1 map and (B) cortex mask

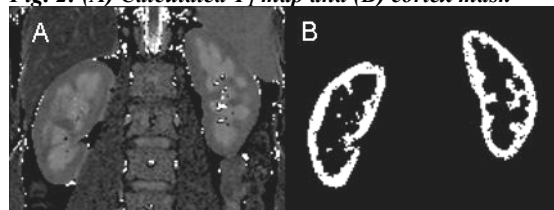


Fig. 3: (A) Transit time map and (B) perfusion map

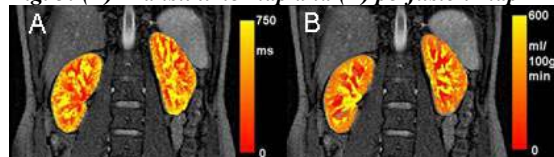


Fig. 4: Single T_I PW images at (A) slice corresponding to multiphase data and (B) an additional slice

