

## Multiphase True-FISP ASL in the Kidney

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**Introduction:** Arterial Spin Labeling (ASL) provides a method to non-invasively assess tissue perfusion, and has recently been applied to study the kidney [1]. The importance of ASL methods to study the kidney has been highlighted due to the diagnosis of Nephrogenic Systemic Fibrosis (NSF), a side effect of gadolinium based contrast agents [2]. Prior ASL studies of the kidney typically acquire data at a single inversion time (TI), and assuming a fixed transit time of the label to the imaging slice, data are fit to a simple model to estimate perfusion [1]. In addition most studies also assume a value of longitudinal relaxation ( $T_1$ ) of the kidney taken from the literature in their fit. An alternative approach is to repeat the collection of ASL data at a number of TIs and to then perform a more complex model fit for transit delay and perfusion rate. However this approach is not generally followed as it is time consuming and can be uncomfortable for patients, particularly if a breath-hold procedure is used as often employed for body ASL data collection. Multiphase ASL [3,4] has been applied in the brain to provide a rapid method of collecting data at a multiple number of inversion times (phases) following a single label pulse. Transit times and perfusion rate can be fitted from the multiphase perfusion weighted (PW) difference signals, and  $T_1$  can be estimated from the control data of the multiphase ASL data set. In the brain, multiphase ASL has been used in combination with gradient echo echo-planar (GE-EPI) readouts to rapidly sample the magnetisation at each phase. However, a GE-EPI readout is problematic for body ASL applications due to the increased susceptibility artefacts. Here we apply multiphase ASL in combination with SENSE accelerated True-FISP in the kidney, and assess the advantages of this method compared to optimal single phase ASL data acquisition.

**Methods:** The study was approved by the local Ethics Committee and all subjects gave written informed consent. 5 subjects were scanned on a 1.5 T Philips Achieva whole body scanner and 4-element SENSE body coil. Multiphase data (96 x 96 matrix, 288 mm x 288 mm FOV and single 5 mm slice) was collected using SENSE 2 acceleration with True-FISP readouts (TR 3.2 ms, TE 1.6 ms, flip angle 60° and half-Fourier acquisition, shot length = 160 ms). The multiphase ASL sequence used an initial delay ( $TI_i$ ) of 100 ms, and subsequent readout spacing ( $TA$ ) of 388 ms with 6 readout phases being acquired (to span a post-label delay of 100 - 2040 ms). The multiphase data sets were acquired during breath-holding, with 3 multiphase data sets acquired per breath-hold (~ 20 s). This procedure was repeated 10 times to provide 30 averages per data set (< 5 minute total acquisition time). 30 averages of a single phase TI = 1100 ms were also acquired (respiratory triggered for optimal data collection) for comparison with the multiphase data. Following data acquisition a base  $M_0$  with long TR was then also acquired.

**Data Analysis:** Each tag and control image pair in the time-series was first realigned to the  $M_0$  base image, by segmenting the kidneys and applying the FLIRT automated linear (affine) registration technique (FSL, fMRIB), as a small degree of motion was apparent despite breathholding. Images were then subtracted in a pair-wise manner on a voxel-by-voxel basis and averaged to form a PW image for each phase. An average multiphase control images data set was then formed, and fit 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  $M_0$  and  $T_1$  maps and a binary kidney mask, to a 2 parameter model for transit time and perfusion [4] using a Powell minimization. An ROI was then drawn in the cortex of the kidney to assess the mean perfusion and transit time across subjects.

**Results and Discussion:** Figure 1 shows the multiphase True-FISP ASL data and the corresponding single TI data set. Figure 2 shows the  $T_1$ , transit time ( $\Delta$ ) and perfusion ( $f$ ) maps estimated from the multiphase ASL data. Both kidneys show very similar quantified characteristics. The mean  $T_1$  in the renal cortex was found to be  $1132 \pm 63$  ms (mean  $\pm$ stdev), in good agreement to  $T_1$  values quoted in the literature [5]. Transit time maps clearly depict the inflow of blood into the kidney as a graded increase in transit times across the cortex. This dispersion in transit times must be taken into account for accurate fitting of perfusion rate. The mean transit time to the renal cortex was  $368 \pm 52$  ms. The perfusion map indicates significant differences between renal cortex and medulla, and feeder vessels are clearly apparent as voxels with high perfusion rates. The perfusion values are within the range of those measured in the literature, with the mean value of perfusion in the cortex being  $246 \pm 21$  ml/100g/min.

**Conclusions:** This study has shown that multiphase True-FISP ASL provides a robust method to study the kidney. The method has significant advantages in providing the assessment of transit time, perfusion rate and  $T_1$  in a total acquisition time of less than 5 minutes. The method shown here has been implemented for a single slice, but can be extended to multiple slices using increased SENSE acceleration factors in future studies.

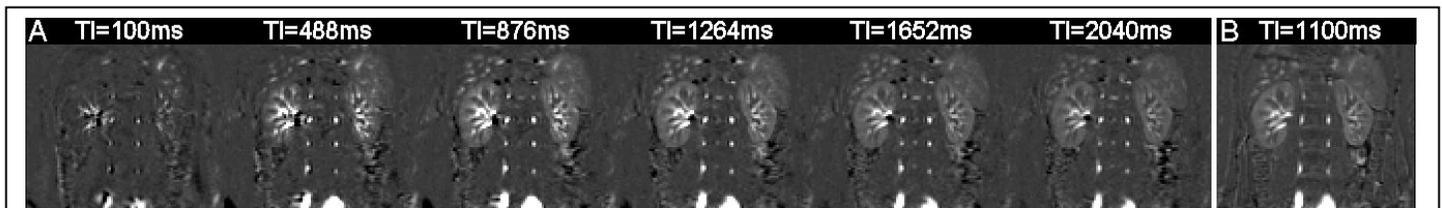


Figure 1: Representative subject: A) True-FISP multiphase PW data and B) True-FISP Single phase PW data TI = 1100 ms.

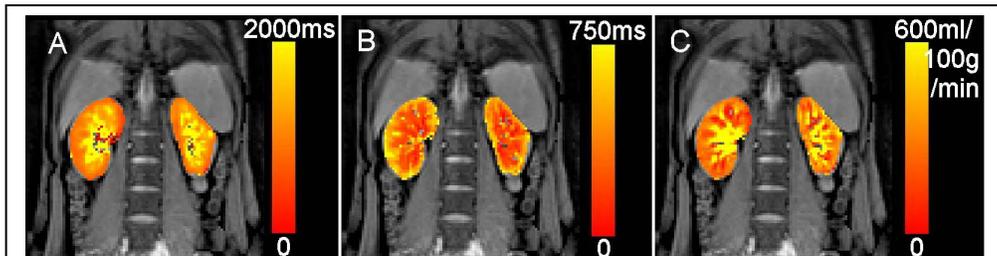


Figure 2: A)  $T_1$  map B) Transit time ( $\Delta$ ) map and C) Perfusion ( $f$ ) map fitted from multiphase ASL data.

### References:

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