THE FEASIBILITY STUDY OF EXPLORING ARTERIAL SPIN LABELING FOR RENAL GLOMERULAR FILTRATION RATE (GFR) MAPPING

Jing Wang[1], Yudong Zhang[2], Yue Zhang[3], Xiaoying Wang[1,2], Jue Zhang[1,3], and Jing Fang[1,3]

[1]*Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, China, People's Republic of,* [2]*Department of Radiology, Peking University First Hospital, Beijing, China, People's Republic of,* [3]*College of Engineering, Peking University, Beijing, China, People's Republic of*

Introduction

For the highly specialized angioarchitecture, the mammal kidney is unique referring to its blood hemodynamics, glomerular filtration and oxygenation. The renal hemodynamic changes and high vulnerability of the renal outer medulla to hypoxia are learned to be extremely associated with acute renal failure. Thus, the quantitative measurement of renal oxygenation and hemodynamics are important in some clinical cases. In this study, we explored a FAIR-ASL to label blood as an endogenous tracer and combined with hypothetic two compartment model for the quantitative mapping of: 1) renal blood R_2*; 2) glomerular filtration rate (GFR). From previous study, the urine T2 is very long (>400ms) (1), then GFR could be estimated by using ASL with a very long TE. If the T2* difference between urine and blood is large enough, the signal in long TE's images will be majorly come from the urine. In this study we adopted multi-TEs protocol for robust blood and urine components model fitting (2). It hopes that this noninvasive MR technique will be useful in quantitative renal function.

Materials and Methods

Total ten healthy young human subjects (5 men, 5 women, 21-29 years) participated in this study. Experiments were conducted on a 3T GE MR scanner with a commercial TORSOPA coil. The single shot SE-EPI with FAIR preparation was adopted for ASL scans, inversion time (TI) of 1600ms (3). The ASL images for R_2* and GFR evaluations were obtained by using a multi-TEs protocol with 6 TEs: 20, 40, 60, 80, 100, and 120ms. An single oblique axial plane through the center of both kidneys was determined with the following imaging parameters: TR= 3200ms, flip angle = 90°, 5mm slice thickness, an inversion slice thickness of 20 mm , an inversion time (TI) of 1500ms. The subjects were trained to hold breath during examinations (20-30s) to avoid motion artifacts. Time-course FAIR-ASL scans were performed to monitor the signal changes due to different TEs (fig. 1). The quantitative RBF maps were calculated by using an established equation on Matlab. The T1 values used for RBF quantification for the cortex, the medulla and the global kidney were set at 1142ms, 1545ms and 1194ms (4). Pixels with high perfusion of more than 600 ml/100g/min in the cortex or more than 250 ml/100g/min in medulla were excluded. By adopted a two-compartment cortical model (2CC) and limed the urine T_2* around 500ms, both blood R_2* and the dimensionless extraction fraction E maps were constructed by fitting the signal time course to a dual-exponential curve. The GFR map was also obtained pixel-by-pixel based on the E and RBF maps.

Results

Benefit from breath-hold and nonlinear image registration, the error due to motion was eliminated from the RBF maps and ΔM images of different TEs (Fig.1). The separable compartment model provides a good fit to the data over the entire time-course range (Fig.2). The mean RBF from ten subjects were estimated as 326.2±63.1 ml/100g/min in renal cortex, 92.4±23.5 ml/100g/min in medulla and 232.1±42.9 ml/100g/min for the whole kidney, which all similar to previous studies (5, 6). The extraction faction E reported by ROI analysis was 0.18±0.09 in cortex, 0.52±0.11 in medulla, and 0.28±0.06 in the whole kidney. The typical GFR values, which were the product of extraction fraction and renal plasma flow (RPF), reported as 29.65±0.43 ml/100ml/min for renal cortex. The GFR estimated by the proposed 2CC model was also confirmed by previous study based on invasive techniques (2). Furthermore, the blood R* estimated by ΔM signals was shown fig.3, which related to the tissue oxygen level.

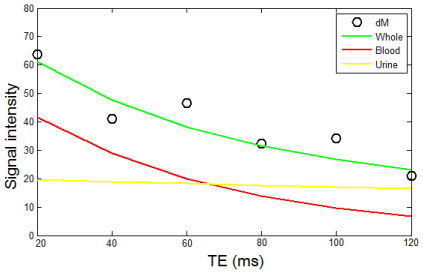

Figure 2. The corresponding time course of the ASL multi-TEs signal and the fitted curve.

Discussion and Conclusion

This study demonstrated a feasible approach for renal GFR mapping based on time-course ASL technique with multi-TEs. By using the proposed method, the RBF, blood R_2* and GFR maps were obtained simultaneously. Befit from the large R_2* difference between renal blood and urine, the separable compartment model demonstrated a robust performance in human application and obtained sufficiently SNR for the following pixel-by-pixel analysis in our study. We hope that this MR technique can be combined with other functional methods such as oxygen extraction fraction (OEF) imaging and diffusion to provide a complete noninvasive assessment of renal status in a single examination.

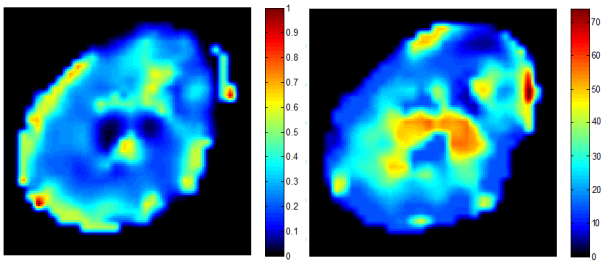

Figure 3: The typical extraction fraction map (Left) and blood R_2* map (Right, Hz).

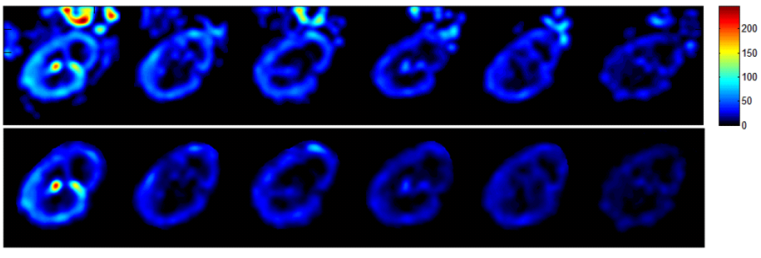

Figure 1: ASL ΔM images before and after nonlinear registration to avoid motion error between varying TEs from a healthy subject. Perfusion signal contrast between the renal cortex and medulla is well demarcated.

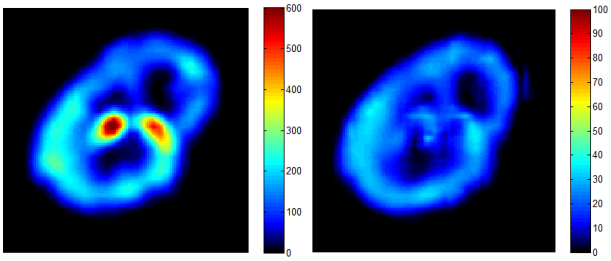

Figure 4: The typical RBF map (Left, ml/100g/min) and GFR map (Right, ml/100ml/min) produced by the two compartment model based on multi-TEs ASL.

References

1. Hamlin DJ, et al. AJR Am J Roentgenol. 1985;145:585-90. 2. Sourbron SP, et al. Invest Radiol 2008;43:40-48. 3. Wong, et al. MRM 1998;39:702. 4. de Bazelaire CMJ, et al. Radiology 2004;230:652-659. 5. Robson PM, et al. Magnet Reson Med 2009;61:1374-1387. 6. Roberts DA, et al. Radiology 1995;196:281-286.