Blood Oxygen-Level Dependent (BOLD) MR Imaging of Diabetic Nephropathy-Preliminary Study

Z. J. Wang[1], R. Kumar[1], B. M. Yeh[1], S. Banerjee[2], and C-Y. Hsu[3]

[1]Department of Radiology and Biomedical Engineering, University of California, San Francisco, San Francisco, California, United States, [2]Global Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States, [3]Department of Medicine, Division of Nephrology, University of California, San Francisco, San Francisco, CA, United States

Introduction:

Chronic renal hypoxia has been increasingly recognized to play a role in the development of diabetic nephropathy [1]. BOLD MRI has been used to assess renal oxygenation [2]. The purpose of our study is to evaluate renal BOLD signal in healthy volunteers and in patients with diabetic nephropathy, and to determine whether BOLD MR signal correlates with the degree of kidney disease.

Material and Methods:

The study was approved by our Committee on Human Research and is HIPPA compliant. BOLD MR imaging was performed in 4 healthy subjects (control group), 4 patients with stage 1 or 2 chronic kidney disease due to diabetes (mild disease group: eGFR $\geq$ 60 mL/min/1.73m^2, but with proteinuria indicating kidney injury), and 4 patients with stage 3, 4 or 5 chronic kidney disease due to diabetes (moderate to severe disease group: eGFR < 60mL/min/1.73m2). The eGFR was obtained within 14 days of MRI. BOLD MRI was performed on a 1.5T system (Excite, GE Healthcare, WI) with an eight channel cardiac receiver array coil (USA Instruments) using a two dimensional (2D) multiple echo gradient echo sequence with 12 echoes: TR 65ms, TE 3-60ms, flip angle 30, slice thickness 5mm, matrix size 256x256. Five coronal images were obtained in breath-held acquisition through the mid kidneys. R2* maps were generated using software MIStar (Apollo Medical Imaging, Melbourne, Australia). For each subject, 4-6 ROIs were placed in the cortex and 4-6 in the medulla on the R2* maps, and averaged to obtain a mean cortical R2* value and a mean medullary R2* value. Statistical analysis of the mean cortical and medullary R2* values was performed using two sample t-test.

Results:

The mean cortical and medullary R2* for each group were displayed in the figure below. The mean medullary R2* values in the control group (19.84 ±1.97 sec^{-1}) were significantly higher than those in the mild disease group (16.18±1.76 sec^{-1}, p = 0.03), which were in turn significantly higher than those in the moderate to severe disease group (13.36 ± 0.91 sec^{-1}, p=0.03). There was no significant difference in cortical R2* values among the three groups (p >0.05). A multiple logistic regression model using patient age and the degree of kidney disease as variables showed that the degree of kidney disease was independently associated with a decrease in medullary R2* values (p = 0.004), while age was not associated with changes in medullary R2* values (p=0.9).

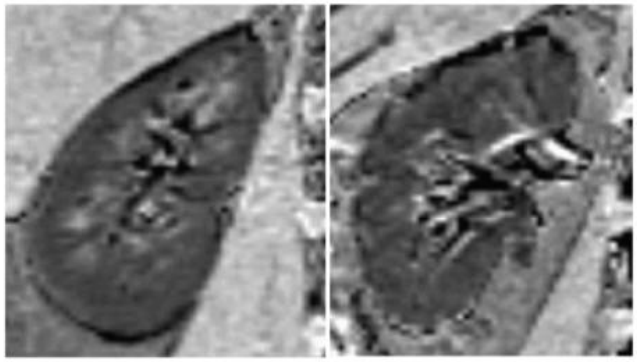

Figure 1: R2* maps of a normal subject (left) showing visible increased brightness in the medulla compared to the cortex, and of a patient (right) with moderate renal disease with GFR = 34 showing reduced brightness (corresponding to reduced R2*) in the medulla compared to the cortex.

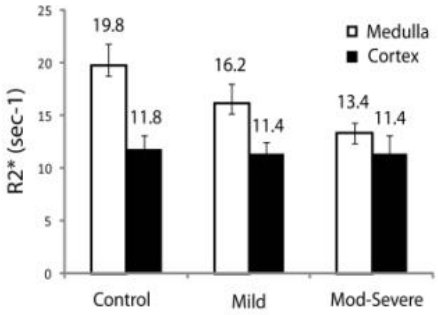

Figure 2: Bar graph of medullary and cortical R2* of the 3 groups; the medullary R2* was the highest in control group, and lowest in patients with moderate to severe renal disease (p =0.03 for both).

Conclusion:

The preliminary data showed decreased medullary R2* values (corresponding to increased oxygen bioavailability) in patients with diabetic kidney disease compared to healthy volunteers; and the decrease in medullary R2* values appeared to be related to the degree of kidney disease. Our BOLD MR data in patients with diabetic renal disease differ from previous reports of early BOLD MRI changes of reduced medullary oxygen bioavailability in animal model of diabetic nephropathy [3.4]. Possible explanations for our observation include tubular damage and/or decreased tubular NaCl transport in chronic diabetic kidney injury, resulting in less oxygen consumption. While larger studies are needed to confirm our initial observation and clarify the relationship between R2* and renal oxygenation in chronic kidney disease, BOLD MR imaging may be a useful tool to assess the degree of chronic diabetic renal disease noninvasively.

References: [1] Palm F. Clin Exp Pharmacol Physiol 2006; 33:997-1001. [2] Prasad PV, et al, Circulation 1996; 94:3271-3275. [3] Ries M, et al. JMRI 2003; 17:104-113. [4] dos Santos EA, et al. Invest Radiol 2007; 42:157-162.