Determining the Correlation of Cortical and Medullary Oxygenation and Perfusion in Transplanted Kidneys by Functional MRI

A. L. Wentland[1,2], E. A. Sadowski[2], A. Djamali[3], B. N. Becker[3], F. R. Korosec[1,2], T. M. Grist[2], and S. B. Fain[1,2]

[1]Dept. of Medical Physics, University of Wisconsin School of Medicine and Public Health, Madison, WI, United States, [2]Dept. of Radiology, University of Wisconsin School of Medicine and Public Health, Madison, WI, United States, [3]Dept. of Nephrology, University of Wisconsin School of Medicine and Public Health, Madison, WI, United States

INTRODUCTION

The kidney controls cortical and medullary blood flow (perfusion) to maintain a balance between oxygenation and tubular function. In animal studies, both cortical and medullary perfusion have been shown to correlate with changes in renal function (as measured by creatinine levels) (1-3). Oxygenation in the kidney is maintained at stable levels over a wide range of creatinine and perfusion levels. Functional MR imaging is able to non-invasively measure the blood flow using MR perfusion techniques and oxygenation by using blood oxygen level dependent (BOLD) MRI techniques in the cortex and medulla. The goal of this study was to determine if there is a significant correlation between kidney function (creatinine levels), perfusion, and oxygenation in the cortex and medulla of transplanted kidneys.

MATERIALS AND METHODS

Seventeen subjects with recent renal transplants (less than four months) were enrolled with the written consent of the subjects. IRB approval was obtained according to institutional guidelines. Five of the seventeen transplant patients had a normal functioning allograft (creatinine = 1.0 to 2.4 mg/dl), four patients had an allograft with acute tubular necrosis (creatinine = 1.4 to 7.1 mg/dl), and eight patients had an allograft with acute rejection (creatinine = 2.1 to 7.7 mg/dl). Images from a T_2*-weighted echo planar perfusion sequence and a BOLD multi-echo gradient-recalled echo sequence were acquired on all subjects in a 1.5 T MRI system (Signa Excite, GE Healthcare, Milwaukee, WI, USA) using a four-element phased array torso coil. An MR perfusion sequence was implemented during gadodiamide injection (0.1 mmol/kg).

From the perfusion images mean cortical and medullary blood flow measurements (ml/100g/min) were obtained. Concentration versus time curves placed on the kidney and the aorta were analyzed using custom MATLAB scripts (MATLAB version 6.0, The MathWorks Inc., Cambridge, MA, USA). From the BOLD images, color R_2* maps were generated using FuncTool (Advantage workstation, GE Healthcare, Milwaukee, WI, USA), ROIs were placed in both the cortex and medulla, and mean R_2* values were recorded as s^{-1}.

Average cortical and medullary R_2* measurements and average cortical and medullary perfusion measurements for the seventeen subjects were plotted. Pearson correlation coefficients were computed to compare cortical and medullary perfusion measurements, cortical and medullary R_2*, creatinine, and hematocrit.

RESULTS AND DISCUSSION

For the seventeen renal transplant patients, the average value for cortical R_2* measurements was 14.5 ± 7.1 s^{-1} and the average for medullary R_2* measurements was 19.3 ± 4.5 s^{-1} (Figure 1). The average for cortical perfusion measurements was 324.4 ± 141.3 ml/100g/min and the average for medullary perfusion measurements was 180.1 ± 96.2 ml/100g/min for the seventeen renal transplant patients (Figure 1). There were statistically significant correlations between cortical and medullary perfusion (r = 0.67; p = 0.0034), cortical perfusion and creatinine (r = -0.51; p = 0.0367), medullary perfusion and creatinine (r = -0.63; p = 0.0067), and medullary perfusion and medullary R_2* (r = 0.50; p = 0.0431) (Table 1). There was no statistically significant correlation between R_2* values and creatinine. Hematocrit did not correlate with perfusion measurements, R_2* values, or creatinine.

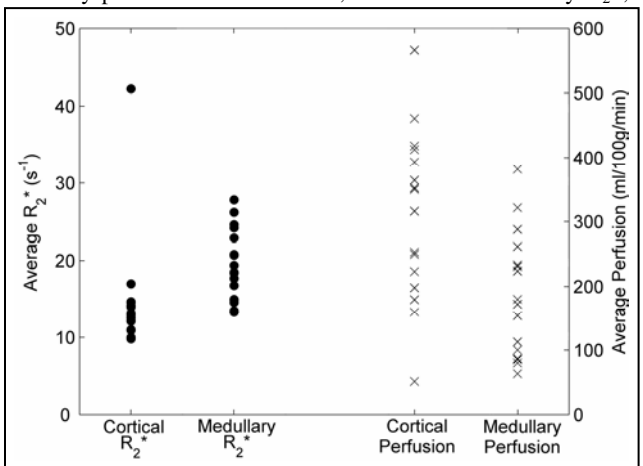

Figure 1. Scatter plot showing average cortical and medullary R_2* measurements and average cortical and medullary perfusion measurements in seventeen renal transplant patients. The left y-axis depicts the range of values for R_2* measurements (s^{-1}) and the right y-axis depicts the range of values for perfusion measurements (ml/100g/min).

Table 1. Pearson correlation coefficients calculated from seventeen renal transplant patients comparing cortical renal perfusion, medullary renal perfusion, cortical R_2*, medullary R_2*, creatinine (Cr), and hematocrit (Hct). Table values with a * are statistically significant.

	Cortical Renal Perfusion	Medullary Renal Perfusion	Cortical R_2*	Medullary R_2*	Cr	Hct
Cortical Renal Perfusion	1.00	0.67*	0.48	0.44	-0.51*	0.23
Medullary Renal Perfusion		1.00	0.22	0.50*	-0.63*	0.08
Cortical R_2*			1.00	0.14	-0.05	0.05
Medullary R_2*				1.00	-0.47	0.25
Cr					1.00	0.07
Hct						1.00

CONCLUSIONS

Utilizing functional MRI to measure perfusion and oxygenation in the cortex and medulla of transplanted kidneys with varying function (varying creatinine levels), we demonstrated a negative correlation between renal function (creatinine) and perfusion. No correlation was identified between renal function (creatinine) and oxygenation values (R_2*). These results agree with animal studies that demonstrate the ability of the kidneys to maintain oxygenation despite changes in kidney function, and to some degree perfusion.

REFERENCES

1. Just A, Arendshorst WJ. Dynamics and contribution of mechanisms mediating renal blood flow autoregulation. Am J Physiol Regul Integr Comp Physiol 2003;285(3):R619-631.
2. Brezis M, Heyman SN, Epstein FH. Determinants of intrarenal oxygenation. II. Hemodynamic effects. Am J Physiol 1994;267(6 Pt 2):F1063-1068.
3. Ojo AO, Wolfe RA, Held PJ, Port FK, Schmouder RL. Delayed graft function: risk factors and implications for renal allograft survival. Transplantation 1997;63(7):968-974.