Renal Perfusion Measured Pre- and Post-transplantation with ASL MRI in Donor-Recipient Pairs

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INTRODUCTION: Monitoring patients post-transplantation for changes in renal function both safely and non-invasively is important in prolonging allograft function. Renal perfusion is not routinely measured in the clinical setting today, yet the literature suggesting its clinical utility is continually expanding. Using gadolinium-based MRI contrast agents in patients with transplanted kidneys remains a concern due to its association with nephrogenic systemic fibrosis. The purpose of this study is to measure and compare renal perfusion using a non-contrast, arterial spin labeling (ASL) MR perfusion technique in donor-recipient (DR) pairs before and after kidney transplantation. A FAIR-bSSFP ASL technique was chosen based on literature results demonstrating feasibility[1,2], reproducibility[3], correlation with microsphere perfusion[4], and clinical potential[5,6].

MATERIALS AND METHODS: This HIPAA compliant study was approved by our institutional human subjects review committee and written informed consent was obtained from all subjects. For thirteen DR pairs, an ASL MR exam was performed one day prior to transplantation in the donor (baseline), and again at three months post-transplantation in both the donor's remaining kidney and the genetically-identical, transplanted kidney in the recipient. To date, four of the thirteen DR pairs have also returned for an MR exam one year post-transplantation. Subjects refrained from fluids for twelve hours prior to the MR examination. *ASL Acquisition* ASL perfusion images were acquired on a 1.5 T MR scanner (GE Healthcare) following a 1.2 second delay using a 2D FAIR-bSSFP technique (parameters: TR/TE/flip = 4.6/2.3ms/70°, BW = 83.33 kHz, FOV = 34 cm, and matrix = 128 x 128, slice thickness = 8 mm). An oblique-sagittal slice was used to avoid major feeding vessels. Respiratory coaching was provided prior to the scan and imaging was triggered during the expiration phase until 32 control-tag image pairs were acquired (6-9 minutes). *Segmentation and Processing* Data was processed with custom scripts written in MATLAB (version 7.5, The MathWorks Inc.). After rigid registration using normalized mutual information, the cortex and medulla were segmented via interactive threshold techniques. Using a one compartment ASL model, the average difference between control and tag was used to calculate perfusion based on known scan parameters and assumed values[7] of $T1_{cortex}$ = 966 ms, and $T1_{medulla}$ = 1410 ms. ASL perfusion values from all the pixels of a given tissue (e.g. cortex) were averaged for each kidney. *Statistical Analysis* A Wilcoxon signed-rank test was used to determine any statistical differences in perfusion ($p<0.05$).

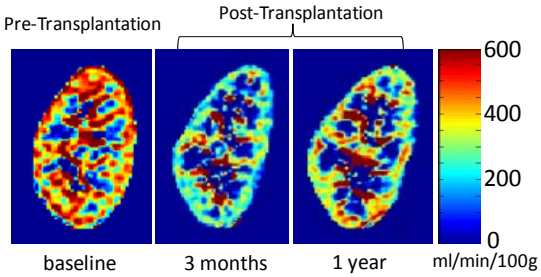

Figure 1 Perfusion maps for a single kidney acquired in the donor pre-transplantation (baseline), and in the recipient at 3 months and 1 year post-transplantation. Note the decrease in cortical perfusion from baseline to 3 months and subsequent rise in perfusion at 1 year.

RESULTS AND DISCUSSION: Perfusion maps for a typical result in a donated kidney demonstrate a decrease in cortical perfusion from baseline (pre-transplantation) to 3 months post-transplantation followed by an increase in perfusion that remains below baseline at 1 year (**Fig 1**). These changes in perfusion were typical for the other transplanted kidneys in the study (**Fig 2**). The decrease in mean cortical perfusion at 3 months was statistically significant across kidneys ($p = 0.003$), and an increase in perfusion at one year was observed in three of the four kidneys, although this was not significant ($p = 0.25$) at this preliminary stage of the study. Calcineurin inhibitors were used as anti-rejection medication in these transplant subjects which can cause a decrease in perfusion to the kidney. Transplantation may also induce tubular injury and although this is minimized in living donor allografts, there still may be an effect on kidney function. There were no other significant changes, including no significant changes in medullary perfusion at any of the time points studied. Similar to the trend observed in the transplanted kidneys, cortical perfusion tended to increase at one year in the donors' remaining kidneys (**Table 1**). We are interested to see if these trends continue as more of the donors and recipients return for the one year exam.

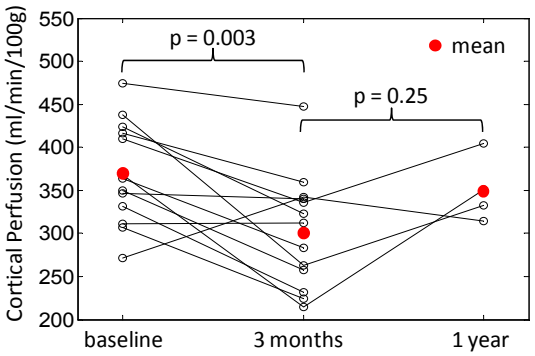

Figure 2 Cortical perfusion pre-transplantation (baseline) in the kidney to be transplanted, and post-transplantation at 3 months and 1 year in the recipient. The decrease in perfusion from baseline to 3 months was statistically significant ($p=0.003$). A subsequent increase in perfusion was observed in three of the four kidneys scanned at one year.

CONCLUSIONS: The cortical perfusion of the transplanted kidneys decreased significantly after transplantation, possibly due to loss of function or use of anti-rejection medications in the recipients. There was a trend of increased perfusion in these kidneys, as well as in the kidneys remaining in the donors, between 3 months and 1 year after transplantation. Further longitudinal studies over the next three years will determine if this trend continues and becomes statistically significant.

		N = 13			*N = 4*		
Transplanted Kidney in Recipient		**Base**	**3 Mo**	**P-val**	**3 Mo**	**1 Yr**	**P-val**
	C	***370***	***303***	***0.003‡***	289	351	0.25
	M	51	53	0.42	52	52	1.0
		*N = 10**			*N = 3†*		
Remaining Kidney in Donor		**Base**	**3 Mo**	**P-val**	**3 Mo**	**1 Yr**	**P-val**
	C	389	386	0.77	352	393	0.25
	M	74	57	0.43	26	65	0.25

Table 1 Cortical (C) and medullary (M) perfusion across time points for transplanted and remaining kidneys. ‡***indicates statistical significance***. *3 donors have yet to return for the 3 month exam. †1 donor has not yet returned for the 1 year exam. Perfusion values are listed in ml/min/100g.

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