Magnetic Resonance Imaging Measurement of Renal Blood Flow Determined On First Pass Gadolinium-Chelate Perfusion

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Introduction: Amongst the most important measures of renal function include glomerular filtration rate and blood flow to each kidney. There has been development and validation of gadolinium-chelate perfusion MRI techniques for the evaluation of glomerular filtration based on gadolinium-chelates that behave as a filtered agent without active excretion or uptake from the renal tubules. It would be a significant contribution if a perfusion technique could additionally be used to measure the renal blood flow. The current standard for measurement of renal blood flow using MRI is based on phase contrast imaging. This method requires several additional steps prior to the actual phase-contrast flow sensitive acquisition and must be repeated for each kidney separately. A perfusion method for renal blood flow measurement would provide a potentially simplified alternative that may be a more robust and generally applicable approach to clinical applications, even in the setting of patients with anomalous vascular anatomy or unusual renal morphology or positioning, including post-transplant or post-traumatic kidneys. Our objective is to develop a perfusion MRI renal blood flow measurement technique based upon a simple 2-compartment kinetics model. In this study we develop and validate an approach using phased-array surface coils combined with a gadolinium enhanced 3D gradient echo Thrive technique with high parallel processing SENSE acceleration to achieve the necessary acquisition rate.

Materials and Methods: Five human subjects, 4 normal volunteers and 1 patient (average age = 33yrs; females = 1), agreed to participate in this study. All subjects signed informed consent forms prior to the study. The patient was found to have normal renal arterial anatomy with solitary renal arteries free of stenotic lesions, in addition to a normal serum creatinine acquired within one week of the MR study. All normal subjects had no history of renal disease or hypertension. The phase contrast technique was a gradient-echo/EPI hybrid sequence performed perpendicular to the vessel of interest following localization in two planes (coronal and axial). Image parameters were as follows: 200mm^2 FOV, 176 matrix (recon to 256), TR/TE/flip = 24/8.6ms/35, EFI factor = 7, 6mm slice thickness, ~25ms temporal resolution, 12-16 phases, and 98 Hz/px bandwidth. The breath hold time was typically 20 seconds. Regions-of-interests (ROIs) were placed over the renal artery cross-section, and flow was calculated from the average velocity multiplied by the area of the ROI. Renal perfusion imaging was performed during the first-pass of 0.1mmol/kg Gd-DTPA (Magnevist) using a 3D spoiled gradient echo technique with fat saturation and centric-radial k-space acquisition using a 430mm^2 FOV, 96 matrix (60% scan percentage, recon to 256), TR/TE/flip = 3.7/1.7ms/30, 30 slices at 2.8mm slice thickness, TFE factor = 120, 0.9s per dynamic, and SENSE factor = 3. Total blood flow to the kidney (F) was calculated from the first-pass perfusion of Gd-chelate over the time window where venous concentration is zero (~7 seconds). Hence, Fick's Law states:

$$C_T(t) = \frac{F}{V}\int_0^t C_a(s)ds\,, \qquad [1]$$

where C_T is the measured tissue concentration in the kidney, V is the kidney volume, and the integral represents the Gd accumulation in the artery. F was approximated computationally by minimizing (least squares) the difference between C_T and the calculated integral value. A paired student's t-test was used to compare phase contrast and renal blood flow perfusion data, with significance being <0.05.

Results: Figure 1 shows sample images of renal blood flow perfusion (MIPs) in one volunteer, accompanied by a numerical fit of Eq. [1] to the acquired data (left kidney). The fit and image data begin to diverge after the appearance of contrast agent in the renal vein. Table 1 compares the flow determined from the perfusion data with mean values from phase contrast, in both the right and left kidney. Overall, the data using both methods were not significantly different from one another (p>0.15).

Conclusions: This report describes and validates a relatively easily implemented methodology for individual renal blood flow measurement based on gadolinium first pass perfusion. Our experience suggests that the perfusion technique may be more robust than other currently available methods, and we believe this is the first demonstration of this approach as applied to renal blood flow.

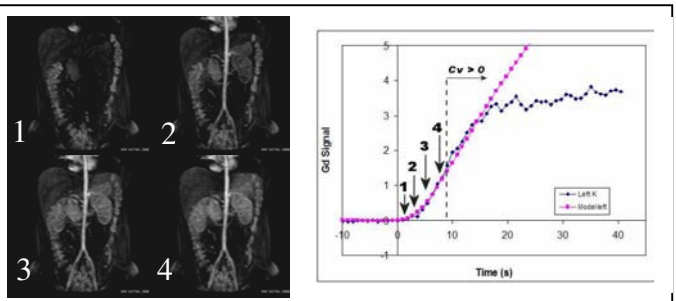

Figure 1. Mapping of kidney perfusion to flow.

Table 1. Renal Blood Flow Comparison

	Perfusion (ml/s)		Phase Contrast (ml/s)*	
Subject	Left	Right	Left	Right
1	7.5	8.0	6.9	9.0
2	6.5	5.5	4.9	5.3
3	7.0	7.0	4.7	5.1
4	7.4	6.3	8.1	5.1
5	8.8	9.1	13.3	9.0

**mean flow over cardiac cycle*