Measurement of Filtration Fraction using 2D Look-Locker Technique in Humans at 3.0T

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INTRODUCTION

Over the last decade there is increasing evidence that renal oxygenation can be evaluated using BOLD MRI [Circulation, 1996. 94(12):3271-5]. These measurements may have unique applications in the evaluation of kidneys with chronic kidney disease (CKD). In late stages of CKD, it has been shown that renal oxygenation may actually be higher than controls [*Kidney Int*. 2002;61:542]. It was also suggested that filtration fraction (defined as the ratio of GFR to renal blood flow) may be a useful parameter to evaluate oxygen utilization. MRI in combination with Gd-chelates offers an attractive means to measuring filtration fraction (FF) [Radiology, 2002. 223(1):76-82]. In this study, we have examined the preliminary feasibility of measuring FF(Gd) in a small group of healthy subjects using a 2D Look-Locker method based on spiral acquisitions. Because there are no simple methods to estimate FF to use as a reference, we have additionally estimated flow in the renal arteries to allow for estimation of single kidney glomerular filtration rate (SKGFR). This was compared to GFR estimated from serum creatinine using Cockcroft-Gault method.

MATERIALS AND METHODS

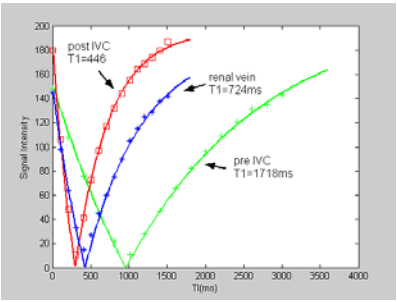
Subjects: Eight healthy subjects with no known renal disease voluntarily participated in the study (29±3.5 years old). Subjects gave informed consent according to the protocol approved by the Institutional Review Board prior to taking part in the study. Blood was drawn for creatinine and hematocrit estimation. In each subject pre-contrast T_1 was measured in the inferior vena cava (IVC), followed by 2 injections of Gd-DTPA (0.1ml/kg each separated by about 25 mins). Ten minutes following the each administration of contrast, T_1 measurements of IVC (assumed to reflect renal arterial T_1) and renal veins were obtained. Flow in renal artery was also measured.

T_1 measurements: We used a modified implementation of a 2D Look-Locker sequence recently described [*AJR* 2004;183:343] on a short bore Signa Twin speed 3.0T scanner (GE Healthcare). Following a non-selective adiabatic inversion pulse, the T_1 recovery was sampled at sixteen equidistant time points. The acquisition sequence is an 8-arm spiral sequence with 4096 points along the readout. During one TR (typically 1.6 s for post- and 3.2 s for pre-contrast), 1 arm of the spiral was acquired at every 100 ms (TI) for TR=1600ms and 200ms for TR=3200ms. Other acquisition parameters include (TE = 6.5 ms, flip angle = 10, NEX = 8, BW = ±125 kHz, thk=5 mm). All acquisitions were performed during free breathing. The excitation pulses used were water-selective pulses to minimize off-resonance artifacts. T_1 measurements were obtained using a non-linear 3-parameter iterative curve-fitting technique implemented in a custom research software package (Cinetool, GE Healthcare).

Flow quantification: A standard phase contrast imaging technique based on the relationship between measured phase shifts and flow velocity was used. Flow measurements were obtained using the Advantage workstation (GE Healthcare).

FF and MRI GFR calculation: single kidney FF = (T1pre/T1v) ▪ (T1v-T1a) / (T1pre-T1a); SKGFR = renal blood flow ▪ (1-hematocrit level) ▪ EF [Radiology, 2002. 223(1):76-82].

RESULTS



Subject #	FF(1)	FF(2)	Flow(1) (ml/min)	Flow(2) (ml/min)	Estimated GFR (ml/min)	MRI derived GFR(1) (ml/min)	MRI derived GFR(2) (ml/min)
1	0.35	0.36	515	503	100	93	94
2	0.32	0.31	482	446	95	91	82
3	0.35	0.38	327	295	83	64	63
4	0.34		611		155	120	
5	0.44	0.39	531	550	133	123	113
6	0.28	0.25	258	693	102	39	95
8	0.5	0.36	541	475	110	270	171

Table Note: FF(1), Flow(1),MRI derived GFR(1) and FF(2), Flow(2) and MRI derived GFR(2) were measured following 1st and 2nd Gd injection respectively. Estimated GFR was based on Cockcroft-Gault (CG) formula [Am J Kidney Dis, 2005. 46(2): 233-41]**.**

Figure: Plot showing the mean values within the ROIs and the fitted T_1 relaxation curve for each ROI: pre-Gd IVC (green), post-Gd IVC (red) and left renal vein (blue) from one subject following the first injection. Note the difference in the post-contrast IVC and renal vein curves suggesting longer T_1 and hence lower gadolinium concentration in the renal vein.

DISCUSSION AND CONCLUSIONS:

The FF estimates seem to be reproducible within each subject when performed 10 min following two 0.1 m/kg of Gd-DTPA separated by about 25 min (Table 1). Flow measurements also seem to be reasonably well reproducible (except in subject #6). The measurements are in general agreement with literature values [J Vasc Interv Radiol, 2005. 16(6): 807-14], and the calculated SKGFR is well correlated with the estimate based on serum creatinine. In one subject (#3) measurements were also obtained at 1.5 T on a different day and they matched with those at 3.0 T. However, the MRI measurements reported are for only the left kidney. In most subjects, locating a slice perpendicular to the right renal vein proved to be challenging given the natural anatomy. In a few subjects (*e.g.* #4,7) the susceptibility artifacts probably due to excessive bowel gas limited 2D LL image quality. In one subject (#8) with horseshoe kidney, the data seemed less reproducible, e.g. FF measurements were substantially different following 1st and 2nd injections.

Coulam *et al* [Radiology, 2002. 223(1):76-82] had previously validated the MRI derived FF(Gd) measurements against FF(inulin) measurements in an animal model of unilateral stenosis. The values for FF(Gd) from this study are comparable to those in that report. Further studies with pharmacologically induced changes in FF might be useful in validating the method to follow changes and/or to distinguish kidneys with different FF.

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