Measuring renal function during routine clinical MR exams: Is 5 min enough?

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Introduction

Magnetic resonance renography (MRR) for assessing renal function has potential for wide clinical application as an adjunct to conventional imaging studies for indications ranging from renal masses to kidney transplants to renovascular disease. Glomerular filtration rate (GFR), the most important measure of single-kidney function, can be reliably identified using ultra-low dose DCE-MRI and appropriate data analysis techniques (1-4). Given limitations on total scan duration, a short MRR scan time has advantages of patient convenience and lower cost. Also, repeated measurements, such as GFR response before and after angiotensin converting enzyme inhibitor (ACE-I) would benefit from short acquisition times. We tested our hypothesis that MRR acquisitions less than 5 min are sufficient for accurate and precise measurements of GFR.

Methods

Ten patients with suspected renovascular disease underwent DCE-MRI at 1.5 T system (Avanto, Siemens) using a coronal 3D FLASH (TR/TE/flip angle 2.84/1.05/12°, 1.7x1.7x2.5 mm^3 voxel, 3s acquisition) after a 4 ml bolus of Gd-DTPA and 20 ml saline flush both at 2 ml/s. Eight seconds following the start of tracer injection, ten 3D acquisitions were repeated continuously for 30 s. During this time subjects were asked to suspend respiration for as long as possible. Sixteen additional 3D images were acquired during separate 3 s breath-holds for 10 min thereafter. Semi-automated image registration and segmentation (1) of the 3D MRR data sets were performed to produce aortic, renal cortical and medullary signal versus time curves, which were then converted to concentration vs. time curves (2). Using a 3-compartment model (4), GFR was estimated from the concentration versus time curves within different time windows [0<t<t_S]. Nine values for t_S, i.e. scan time, were tested: 2, 3, 4, 5, 6, 7, 8, 9 and 10 min. Reference GFR was measured by ^{99m}Tc-DTPA renal scintigraphy the same morning as MRI. Total GFR was estimated by plasma clearance method, and was split into left and right single-kidney GFR according to renal uptake on gamma camera images at 2-3 min. Correlation coefficient (R) between reference GFR and MRR GFR was calculated for each scan time. One kidney was excluded due to presence of multiple cysts.

We also performed a simulation with scan time t_S. The same values of t_S as above (2-10 min) were tested, assuming a contrast does of 4 ml Gd-DTPA injected iv at 2 ml/s. Simulated arterial input A(t) was obtained by averaging aortic concentrations of multiple subjects after aligning the peak times. Convolving A(t) with impulse retention functions (IRF) of 3-compartment model resulted in tracer concentration versus time curves for renal cortex and medulla (4). Two types of kidney were simulated: normal (GFR 58 ml/min) and dysfunctional (GFR 24 ml/min). The concentration curves were then converted to signal curves, and random noise (5% of pre-contrast cortical signal) was repeatedly added to the signals. Noisy arterial, cortical, and medullary curves were then converted back to concentration. The 3 compartment model was used to estimate GFR. For each simluation setting (scan time and kidney status), the process of adding random data noise was repeated 2000 times. Coefficient of variation (CV), defined as the ratio of standard deviation (STD) and mean of the GFR estimates, was calculated as a measure of precision, and relative deviation (RD) as the difference between mean and the true value divided by the true value. Optimal t_S was defined as the shortest scan time that "preserves" (<10% change compared with scan time 10 min) the precision and accuracy for GFR estimates.

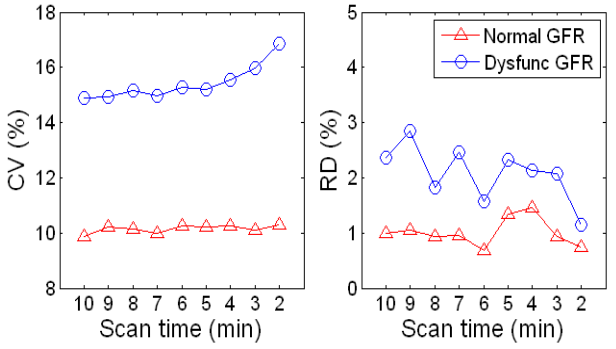

Figure 1. Simulation-derived coefficient of variation (CV) and relative deviation (RD) of GFR estimated from MRR for different scan times.

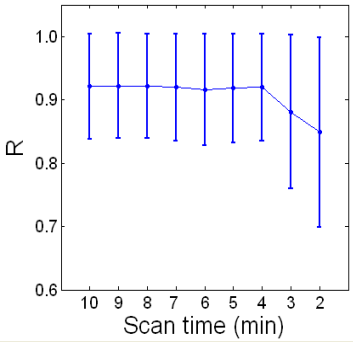

Figure 2. Correlation coefficient (R) between reference and MRR-GFR for different MRR scan times.

Results and discussion

Figure 1 shows the precision (CV) and accuracy (RD) of GFR for different scan times based on simulations. CV of the GFR estimates was consistently higher for dysfunctional kidney than normal kidney, because the mean value of GFR is lower in dysfunctional kidney. For the normal kidney, GFR precision was high and constant for scan times ranging from 2 – 10 min, with CV abound 10%; relative deviation (RD) was less than 2% for all the scan times. For the dysfunctional kidney, GFR precision deteriorated when scan time dropped below 5 min, while the accuracy was high, with RD less than 3%. Patient study included the cases with wide range of renal function: GFR = 3.5 – 80.1 ml/min. Effects of shortened scan time were consistent with predicted (Figure 2). The correlation coefficient between MRR-GFR and reference GFR was ~0.92 for all scan times from 4 to 10 min, and was significantly lower for scan times 3 min (R = 0.88) and 2 min (R = 0.85). Both simulation and patient study suggest that for a regular single-injection MRR for GFR measurement, scan time of 4 min is sufficient to produce GFR with comparable accuracy and precision as for a scan time of 10 min.

Conclusion An low-dose MR renography scan time of less than 5 min appears to be sufficient for GFR measurement, making it practical for routine clinical use.

References. 1. Rusinek et al. MRM p1157 2007; 2. Bokacheva et al. MRM p1012 2007; 3. Lee et al AJP renal physiol p1548 2007; 4. Zhang et al MRM p278 2008; 5. Mickaely et al. Invest Radiol p120 2008.

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