Determination of glomerular filtration rate in cirrhotic patients by MR renography: pilot study

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Introduction: Glomerular filtration rate (GFR) is often impaired in cirrhotic patients. Renal function has a high prognostic value, reflected by the inclusion of serum creatinine (Cr) in the model for end-stage liver disease (MELD) score (1) which is used for transplant prioritization. However, in cirrhotic patients serum Cr is a poor marker of renal function, and low serum Cr can mask underlying renal insufficiency (2). Since cirrhotic subjects routinely undergo liver MRI for cancer screening, we proposed that low-dose Gd-MR renography can be performed as an adjunct to liver MR exams with little added time and contrast material. The goal of our pilot study was to assess the feasibility, accuracy and precision of GFR measurement by MRI as compared to the reference method of urinary clearance of ^{99m}Tc-DTPA.

Materials and methods: This IRB-approved study included 20 cirrhotic patients (8 Child A, 9 Child B, 3 Child C) who were referred for a routine liver MRI. Subjects with MDRD-GFR < 15 mL/min/1.73m^2 were excluded. During the liver MRI at 1.5 T (Avanto, Siemens Healthcare), patients underwent MR renography using a 3 mL dose of standard gadolinium (Gd) contrast (gadoteridol, ProHance, Bracco) followed by 5 minutes of imaging to visualize the passage of the agent through the kidney. The dynamic MRI protocol was performed using a 2D SR-Turbo-Flash sequence with free breathing, imaging 4 slices every 2.1 sec for 5 minutes: two coronal slices through the aorta and kidneys (Fig. 1, left), and two axial slices through the mid portion of each kidney (Fig. 1, right). Three observers estimated GFR by MRI by analyzing the signal from the whole parenchyma using a 2-compartment model (MR-2C) (3) but also from the cortex and medulla separately using a 3-compartment model (MR-3C) (4). Kidneys were manually registered using ImageJ software, and enhancement curves were generated for the aorta and the kidneys. Kidney volumes weighted the results and were measured with a validated semi-automatic segmentation software from arterial-phase 3D VIBE imaging as part of the liver MR exam (5). On the same day, reference GFR was determined by the urinary clearance of ^{99m}Tc-DTPA. GFR was also assessed by Cockcroft-Gault and the 4-variable MDRD Cr-based formulas. Assessed were: measurement bias, the fraction of estimates falling within ±10%, 30% and 50% of the reference GFR (according to National Kidney Foundation guidelines), the coefficient of determination (R^2), and the root mean square error (RMSE). Reproducibility was assessed by the intra-class correlation coefficient (ICC) and the coefficient of variation (CV).

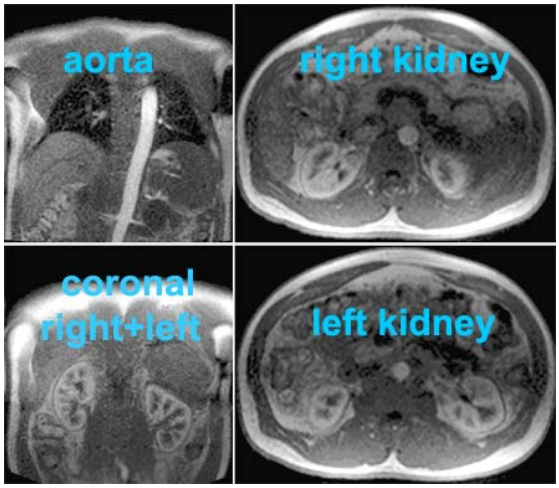

Figure 1: Four slices of the renography at the arterial time after injection of 3 mL of gadoteridol.

Results and discussion: Reference GFR using urinary clearance of ^{99m}Tc-DTPA averaged 71.4 mL/min/1.73m^2 (range, 10.2-112.3 mL/min/1.73m^2). One subject had GFR < 15 ml/min/1.73m2 by radionuclide clearance, despite MDRD GFR > 15 ml/min/1.73m^2. The performance of GFR estimators is reported in the Table 1.

	Accuracy				Precision		Reproducibility	
	Bias ± SD (mL/min/1.73m^2)	Percentage within ± 10% of the reference GFR*	± 30% of the reference GFR*	± 50% of the reference GFR*	R^2	RMSE (mL/min/1.73m^2)	ICC	CV (%)
^{99m}Tc-DTPA	-	-	-	-	-	-	0.91	7.4
Cockcroft-Gault	28.6 ± 20.5	10	40	75	0.61	20.5	-	-
MDRD	24.8 ± 23.8	15	60	80	0.58	23.8	-	-
MR-2C	-3.3 ± 11.8	40	95	95	0.79	12.8	0.96	8.6
MR-3C	-5.8 ± 11.7	35	95	95	0.83	11.7	0.94	12

Table 1. Accuracy, precision and reproducibility of GFR estimators. *Urinary clearance of ^{99m}Tc-DTPA was the reference for GFR.

For both MR-GFR estimators, 95% of the measured values were within 30% of the true GFR values. In contrast, creatinine-based formulas greatly overestimated the GFR. Only 40% Cockcroft-Gault estimators and 60% of MDRD estimators were within this range. MR-GFR values were also more precise than Cockcroft-Gault and MDRD values. Reproducibility of MR-GFR and urinary clearance ^{99m}Tc-DTPA were comparable. Volume measurements, including registration and segmentation of cortex and medulla required about 20 minutes per kidney. The post-processing of renographic images required about 2 minutes per kidney for the 2 compartment model, and 45 minutes for the 3-compartment model because of the need for segmentation of cortex and medulla and more stringent registration requirements. Given comparable results between the two MR models, the MR-2C model is preferred because of its fast processing time.

Conclusion: GFR measurement by MRI is accurate, precise and reproducible and is feasible during routine liver MRI performed as part of standard clinical care for cirrhotic patients. The method adds less than 10 minutes to a standard liver protocol, requires no more than 3 mL gadolinium contrast, and provides GFR estimates significantly more accurate and precise than Cockcroft-Gault and MDRD creatinine-based GFR estimates.

References:

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