The effect of iodinated contrast media on glomerular filtration as evaluated with dynamic 3D-MR Renography

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Introduction

Contrast-induced nephropathy (CIN), known as an adverse event caused by intravascular administration of iodinated contrast media (CM), is clinically diagnosed by an increase in the surrogate marker for GFR, SCrea (1). Unfortunately, SCrea is a rather poor marker for GFR, and is notoriously insensitive to rapid renal functional changes such as the immediate GFR drop induced by iodinated CM (2). Recently, several methods for estimating the GFR from T_1-weighted, DCE MR renography (MRR) data have been published. And the results from these measurements show a good accordance with the renal function measurements derived from ^{99m}Tc-DTPA clearance and scintigraphy (3). Accordingly, in this study, we quantify single kidney GFR with DCE-MRR in a CM-induced acute kidney injury rabbit model. We hypothesized that the technique would be sensitive to changes in glomerular filtration following iodinated CM administration, and more specifically, that the iodinated CM would result in a relatively earlier reduction in GFR. As such, the work would be helpful to understand pathogenesis of CIN.

Materials and Methods

This study was approved by the university animal care and use committee. Ten New Zealand white rabbits (male, body mass range 2.5–3.0 kg) were included, and each acted as its own control. The DCE-MRR images were acquired before the administration of iodinated CM to obtain baseline GFR measures. After a 24-hour control period, the rabbits received an intravenous injection of a nonionic, hyperosmotic iodinated CM, iopamidol-370 (Isovue, 370 mg I ml^{-1}, 796 mOsmkg^{-1} H_2O, Bracco Diagnostics Inc.) with a dosage of 6ml kg^{-1} body weight. DCE-MRR was then performed at 20 minutes after the administration of iopamidol to observe the acute response of glomerular filtration function. Experiments were conducted on a 3.0T MR scanner. A 3D coronal SPGR protocol was prescribed with flip angles of 3° and 15° to acquire data for baseline T_1 estimates. Low dose (0.05 mmol/kg Gd-DTPA) DCE-MRI was then performed using 3D-SPGR (15° flip, TR/TE 3.1/0.9 ms) with volumes acquired every 4 s for 4 minutes. Acquisitions were performed in an oblique coronal plane encompassing both kidneys and the descending aorta. The tracer-kinetic modeling of glomerular filtration is based on a two-compartment exchange model (4, 5), defined by three parameters: renal blood volume fraction V_P, tubular volume fraction V_E and extraction-flow EF actually reflecting GFR. Following T_1 correction, Pixel-wised V_P, V_E and EF maps were fitted with the Levenberg-Marquardt nonlinear least squares algorithm.

Results

Data were successfully analyzed from all 20 kidneys (Fig.1). High-dose iodinated CM significantly decreased cortical V_P (42.53 ± 10.16 % pre-CM vs. 27.23 ± 16.13 % post-CM, paired t test, $p < 0.01$), V_E (22.40 ± 11.69 % pre-CM vs. 11.51 ± 6.58 % post-CM, paired t test, $p < 0.01$) and GFR (31.92 ± 12.52 ml/min/100g pre-CM and 21.48 ± 10.02 ml/ml/100g post-CM, paired t test, $p < 0.01$). It illustrates that iodinated CM produces a rapid renal functional deficiency as regard to renal circulation and glomerular filtration (Fig.2).

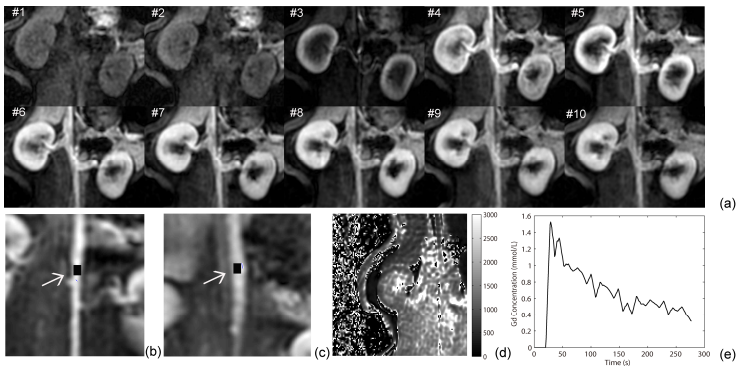

Fig.1. Differential image series of kidneys recorded before and after a bolus injection of Gd-DTPA in a healthy rabbit. (a) Time-resolved images serially obtained before and after Gd tracer injection. (b) Illustration of ROI (arrow) labeled in descending aorta for AIF calculation. (c) Illustration of the ROI (arrow) labeled in IVC for VOF calculation. (d) Baseline T_1 map derived from DESPOT$_1$ method (6). (e) The corrected concentration-time curve of the AIF.

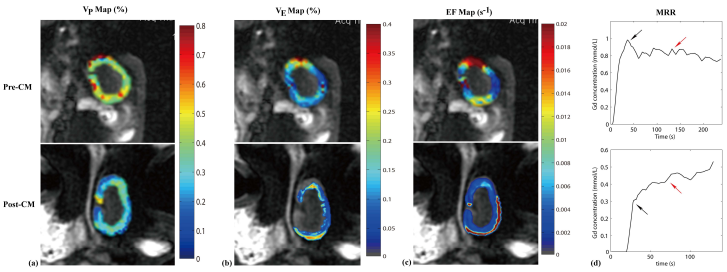

Fig.2. a representative functional response in one rabbit left kidney to the iopamidol administration. The post-CM imaging maps reveal remarkable decreases in V_P (a), V_E (b), and EF (c). The corresponding outer medullary MRR (d) is significantly altered due to iodinated CM administration, characteristic with a decreased tracer concentration, slowed upslope, flattened peak (black arrow) and elevated clearance curve (red arrow).

Discussion and Conclusion

Glomerular filtration is the main function of the kidney. Currently, we have described a proposed way for determining the single kidney GFR noninvasively by using DCE-MRR. The study has demonstrated that nonionic, high-osmolality iopamidol produces an acute hemodynamic response of kidney function that is associated with a significant deficiency in cortical blood circulation following with a prominent decrease in glomerular clearance rate. These findings suggest that non-invasive MRR method may be of value for the detection and quantification of altered glomerular filtration function as the basis for the evaluation of normal and pathological states such as CIN.

References

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