

# Comparison of two methods to determine single kidney GFR from MR renography: A multicompartmental model and Patlak-Rutland analysis

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## Introduction

Dynamic gadolinium-enhanced MR images of the kidneys have been investigated by several groups for the noninvasive measurement of renal function. However, methods of analysis vary across groups. We compared two approaches, a multicompartmental model and Patlak-Rutland method for the determination of single kidney glomerular filtration rates (GFRs) against same day reference nuclear medicine measurements.

## Methods

Dynamic renal perfusion images were acquired on 1.5 T scanner (Avanto, Siemens) in 9 patients using 3D FLASH sequence (TR/TE/flip angle=2.84/1.05/12°). Total observation time was 20 min. Patients received 4 ml (2 mmol) injection of Gd-DTPA over 2 s followed by 20 ml saline flush at the beginning of the scan. Resulting kidney images were segmented into cortex and medulla and the corresponding signal intensity curves were extracted. Blood signal was measured in an ROI placed in the aorta at the level of the kidneys. Tissue and blood signal intensities were converted into concentration of Gd using a reference phantom curve [1]. Pre-contrast T1 values required for the conversion were measured by low-flip angle inversion-recovery prepared TrueFISP method [2]. Resulting Gd concentrations as functions of time were analyzed with a multicompartmental renal model [3] and Patlak-Rutland method [4].

The multicompartmental model uses measured aortic concentration as an input function and models the renal cortex as comprised of vascular and proximal tubular compartments, while the medulla consists of vascular and loop of Henle compartments. Cortical and medullary Gd concentration-time curves are fit, using measured regional volumes as fixed parameters. Glomerular filtration rate was determined as a free parameter of the medullary curve fitting.

The Patlak-Rutland method based on a simplified two-compartment model [4]. GFR was determined as the slope of the plot of  $K(t)/b(t)$  vs  $\int b(t)dt/b(t)$ , where  $K(t)$  is the amount of Gd in the kidney and  $b(t)$  is the concentration of contrast in the aorta, multiplied by (1-Hct), where Hct is the hematocrit (Hct=0.4). Actual concentrations obtained as described above were used to create Patlak-Rutland plots. Time intervals between 45 and 150 s were selected for determination of GFR in most cases, as these were shown to provide the most accurate GFR values [4].

Reference GFRs were determined from  $^{99m}\text{Tc}$ -DTPA blood clearance values (for global GFR), combined with gamma camera based methods to determine split renal function (scintigraphy), and hence single kidney GFR; MR and nuclear medicine studies were performed on the same morning.

## Results

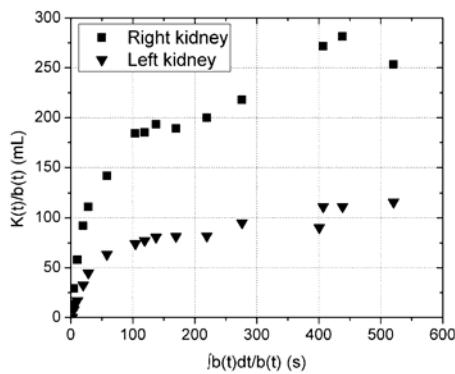


Figure 1. Patlak-Rutland plot

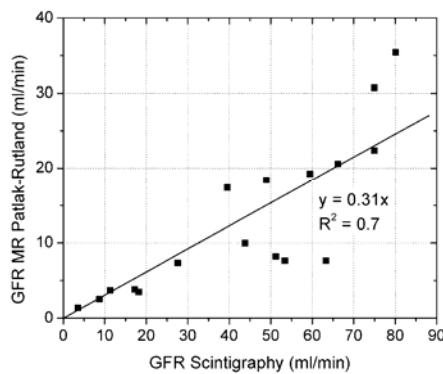


Figure 2. GFR from Patlak method

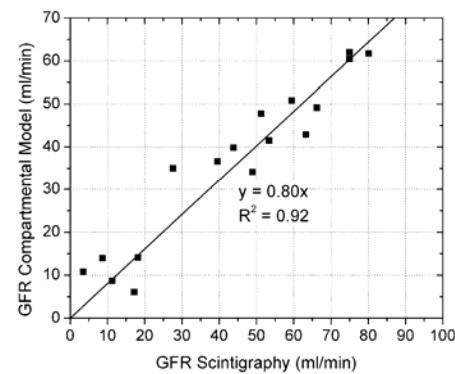


Figure 3. GFR from compartmental model

Typical Patlak-Rutland plot for right and left kidneys in one patient is shown on Fig. 1. GFR values calculated with Patlak-Rutland method (Fig. 2) and multicompartmental model (Fig. 3) are shown versus the reference GFR values determined from nuclear medicine measurements. The correlation between reference single kidney GFR values using the Patlak-Rutland method,  $R^2 = 0.7$ , was significantly lower than that using the multicompartmental model,  $R^2=0.92$ .

## Discussion

Our results show that the GFR values derived from a multicompartmental model are in better agreement with reference values than those obtained by Patlak-Rutland method. Both MR methods underestimate the GFR, however, GFRs calculated by the model more closely approximate GFR. As can be seen from Fig. 1, depending on the choice of the time interval for linear fitting in Patlak-Rutland method, the resulting slope, and therefore GFR, can vary greatly. Using the multicompartmental model method, the concentration-time curves until 600 s after contrast injection were fitted and GFRs were shown to be independent of the choice of time interval. It has been reported that the accuracy of Patlak-Rutland method improves at higher doses of injected contrast [5]. Therefore, our use of a low dose (2 mmol) may not be optimal. Our analysis also does not assume linearity of MR signal intensity with concentration. Additionally, Patlak-Rutland fits are strongly affected by the scatter in the data. Compartmental modeling is free from these drawbacks.

## References

- [1] Rusinek et al. Magn Reson Med 2001;46:312-316.
- [2] Scheffler K., Hennig J. Magn Reson Med 2001;45:720-723.
- [3] Lee V.S. et al. In: Proc Int Soc Magn Reson Med 2005;13 :552.
- [4] Hackstein N. et al. J Magn Reson Imaging 2003;18:714-725.
- [5] Hackstein N. et al. J Magn Reson Imaging 2005;22:406-414.