Measurement of the renal perfusion by means of 2-compartment Patlak analysis from dynamic magnetic resonance imaging

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Introduction
Patlak analysis describes a method for determining the rate constant of tissue uptake of a tracer from the vascular space using values of tracer concentration in tissue and blood. Patlak analysis is most commonly used to determine the tissue uptake of fluorodeoxyglucose during positron emission tomography. Patlak analysis of dynamic magnetic resonance imaging (MRI) data from kidney regions of interest (ROI) has also been proposed as a method to assess renal function. This study was aimed to produce Patlak images of the kidney from dynamic MRI data and to characterize intrarenal variations of perfusion in normal and abnormal human kidneys.

Methods
Ninety patients with 31 kidneys (21 normal, 7 chronic renal failure, 4 renal artery stenosis) underwent MR imaging with a 1.5 T imager (Magnetom Vision, Siemens). Renal perfusion was measured by applying Patlak analysis to time-intensity data from the kidney and aorta during dynamic MRI imaging. Turbo FLASH MR imaging was performed with TR of 1000 msec, TE of 4.2 msec, TI of 515 msec and flip angle of 10°. Gadopentetate dimeglumine (Gd-DTPA) was injected in a dose of 0.02-0.04 mmol/kg as a rapid bolus using a injector, followed by rapid injection of normal saline. Imaging was obtained every one second from 0 to 40 seconds after injection of Gd-DTPA. Perfusion parameters were correlated against patients' age. The renal regional perfusion (cortex or medulla) was determined from parametric images generated using pixel by pixel analysis.

Results
Images demonstrating quantifiable intrarenal variations in perfusion were consistently obtained. Normal cortical and medullary perfusion was 7.06±1.60 ml/min/ml and 2.97±0.83 ml/min/ml, respectively. Cortical and medullary perfusion of chronic renal failure was 3.38±1.33 ml/min/ml and 4.61±2.54 ml/min/ml, respectively. Cortical and medullary perfusion of renal artery stenosis was 4.41±0.34 ml/min/ml and 1.90±0.52 ml/min/ml, respectively. There were significant statistical differences between normal and abnormal kidney in the cortex (p<0.01). A weak correlation was found between kidney permeability and patients' age (cortex: r=-0.38, medulla: r=-0.44).

Discussion
The absence of a noninvasive method of measuring renal cortical and medullary perfusion has prevented direct validation of the quantitative results of the MRI technique in human subjects. Patlak analysis is used to quantify the passage of contrast from intravascular compartment into the extravascular space. Patlak analysis of MRI data will provide information additional to that which can be derived from simple measurements of contrast enhancement within renal cortex and medulla. Simple attenuation measurements will not only reflect physiological processes within the tissue studied but are also dependent upon the pattern of delivery of contrast medium to the tissue from the vascular system.

The absolute perfusion value of 7.01 ml/min/ml for cortex and 2.97 ml/min/ml for medulla obtained in our normal cases slightly overestimated those for the physiological compartments assumed to be cortex and medulla derived from compartmental analysis of the washout of radioactive xenon (4.13 ml/min/g and 1.33 ml/min/g, respectively). Using dynamic MRA, the effects of chronic renal failure and renal artery stenosis on intrarenal hemodynamics can be distinguished. MR perfusion imaging may also distinguish other renal diseases, which manifest as a global reduction of perfusion. One limitation of the technique is that only one axial slice can be studied, and thus, cranio-caudal variations in the distribution of renal perfusion cannot be visualized. Application of rapid sequence may potentially enable volume acquisition of data.

In conclusion, magnetic resonance perfusion imaging creates quantifiable images of renal permeability with a spatial resolution higher than any other functional imaging technique of nuclear medicine. Also, the limitations of radiation burden would be avoided with MRI. MR imaging offers not only morphological information but functional information for tissue perfusion by using a Patlak analysis.

References