Quantitative dynamic MRI using contrast media in renal failure

N. Michoux[1], X. Montet[1], A. Pechere[1], A. Keller[1], F. Terrier[1], J-P. Vallée[1]
[1]University Hospital of Geneva, Geneva, Geneva, Switzerland

Introduction

Numerous studies have demonstrated the potential of dynamic MRI using contrast media injection and T1 weighted sequence to qualitatively assess normal kidney function. New advances in MR signal calibration have increased this potential make it possible to assess kinetic and haemodynamic and functional parameters of the kidney quantitatively. The aim of this study was to compare the renal outflow curves of MR contrast media in normal and renal failure patients using a quantitative model.

Material and method

Thirty patients referred for a kidney MR exam were divided in two groups: a first population with well-functioning kidneys with a normal renal function (n=19, creatinine 75 ± 14 µM) and a second population with renal failure from ischaemic kidney disease (n=11, creatinine 318 ± 163 µM). The perfusion sequence, during the intravenous injection of Gd-DTPA (3 cm^3 at 3 ml/s, Dotarem, Guerbet, FR) consisted of a single 10-mm-slices acquired in the transverse plane through the kidneys using a fast GRE sequence T1-TFE with 90° magnetization preparation (abdominal phased array coil, TR/TE 4.49/1.9 ms, FA 90°, FOV approx. 40 cm, 64x256 with symmetric encoding, ECG- or PPG-triggered, Intera 1.5T MR System, Philips Medical System, Best, NL). Outflow curves were obtained after segmentation of regions of interest in the cortex and medulla of the kidney and in the abdominal aorta. To convert the signal intensity into 1/T1 which is proportional to contrast media concentration, a flow-corrected calibration procedure was used [1]. Transit-time curves were smoothed in order to remove the high frequency fluctuations. Absolute blood flow measurement based on [2] was given by $Q = \max\{slope(1/T1)_{renal}\} / \max\{\Delta(1/T1)_{arterial}\}$ where $slope(1/T1)_{renal}$ is the maximum slope of the initial wash-in of kidney curve and $\max\{\Delta(1/T1)_{arterial}$ is the maximum 1/T1 increase in the aorta. Parameters *Qc* (cortical perfusion), *Qm* (medullary perfusion), *Qa* (medullary accumulation), *Qc/Qm* (perfusion ratio) as well as times to peak Tc and Tm (related to cortical and medullary perfusion phase) and Ta (related to the end of the increasing accumulation phase in the medulla) were calculated.

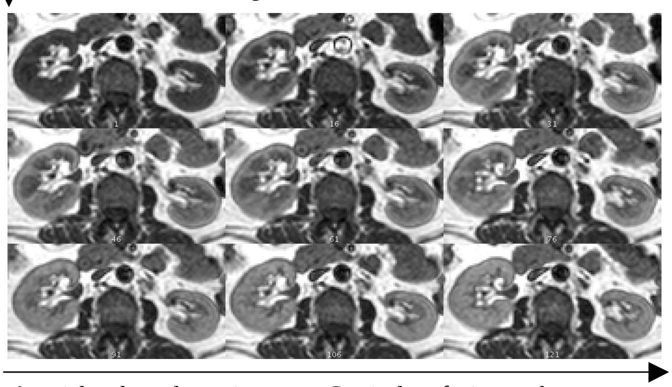
Results

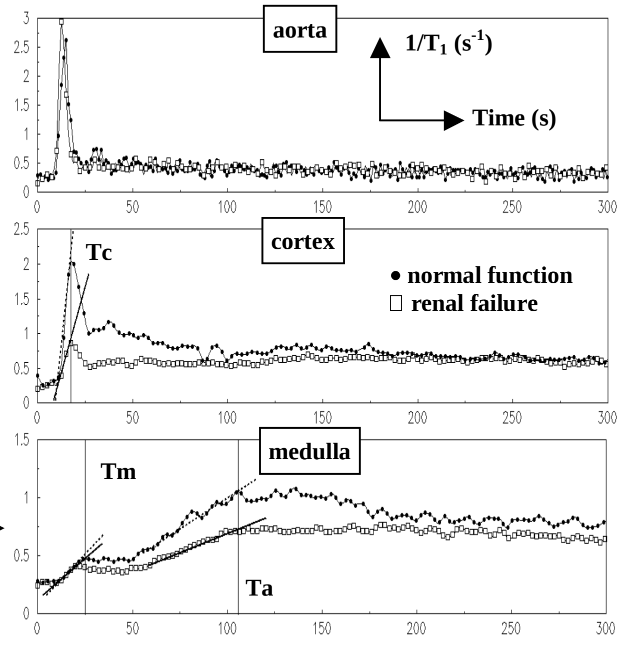
There was a markedly decreased vascularisation in the cortical and medullary regions as well as a significant decrease in the accumulation of contrast agent in the medulla. Furthermore, the reduction in perfusion was higher in the medulla than in the cortex in the case of renal failure. High correlations were found between the creatinine level and the accumulation *Qa* in the medulla (r^2=0.72, p<0.05), and between the perfusion ratio *Qc/Qm* and the accumulation *Qa* in the medulla (r^2=0.81, p<0.05). No significant difference was found in times to peak between both populations despite a trend showing the mean Ta arriving later for renal failure.

Discussion and conclusion

The decrease in cortical perfusion as well as the absence of prolonged time Tc indicated a reduction in the number of functional nephrons in renal failure. The trend for a decrease in *Qc/Qm* in renal failure may have indicated some compensatory mechanisms that remain to be investigated. The significant decrease of the accumulation *Qa* of contrast media measured during the excretory phase, may be a useful parameter to assess early manifestation of renal failure or asymmetry of the disease as it may be encountered in renovascular disease. With advanced MRI methodology, accurate and reproducible images of the kidney can be acquired offering a robust tool for quantifying the function in renal failure. This may have a strong potential in early diagnosis and treatment monitoring.

Selected frames of images acquired with a T1-TFE sequence after injection of Gd-DTPA in a patient with a normal renal function. Shortly after the aorta, the cortex enhances followed by the medulla. Subsequently, cortical-medullary differentiation is lost while the contrast agent diffuses towards the inner medulla.





Arterial and renal transit curves. Cortical perfusion peaks are characterised by high amplitude and high slope in normal function (black circle). Accumulation in the medulla is significantly marked by lower slope in renal failure (open square).

Functional parameters	Tc (s)	Tm (s)	Ta (s)	Max Δ(1/T1) aorte (s^{-1})	Qc (10^{-2}ml/s/100g)	*Qm* (10^{-2}ml/s/100g)	*Qa* (10^{-2}ml/s/100g)	*Qc/Qm*
Normal function	7.4 ± 3.6	9.1 ± 3.6	96 ± 20	1.9 ± 1.0	5.75 ± 3.16	2.24 ±1.79	0.50 ± 0.33	3.8 ± 2.8
Renal failure	8.4 ± 2.8	10.4 ± 2.8	119 ± 27	3.4 ± 1.3	3.00 ± 1.70	1.08 ± 0.59	0.09 ± 0.08	3.1 ± 1.4
Significance	p>0.1	p>0.1	-	p<0.05	p<0.05	p<0.05	p<0.05	p>0.1

Acknowledgements

This work is partially supported by the Swiss National Science Foundation, Grant PPOOB – 68778.

References

[1] Magnetic Resonance in Medicine, 2003, 50 (5), pp: 885-891. [2] European Radiology, 2000, 10, pp: 1245-1252.