Curve fitting of dynamic MRI enhancement data of the kidney

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Introduction

With dynamic MRI the uptake and passage of the contrast agent in the kidney can be observed separately in cortex and medulla [1]. The responses after bolus injection of a T1 contrast agent reveal a variety of features. Both the cortical and the medullary curves usually show three maxima, corresponding to the vascular first pass of the bolus, the early nephron filling, and the late nephron filling [2]. For clinical interpretation of the enhancement curves quantitative knowledge of amplitude and time of these peaks is desirable. We developed a curve fitting method and tested its performance.

Data

The data are obtained with dynamic MRI with a strongly T1 weighted spoiled GRE sequence (TR/TE/flip = 11ms/3.4ms/60°) with a 400 mm field of view, a slice thickness of 5 mm and a resolution of 256 x 256. The series of 256 images, 2 s / image, starts 20 s before bolus injection of 0.3 mmol/kg Gd-DTPA.

Ten patients with renal transplants and no clinical symptoms of rejection were examined twice in two sessions at less than two weeks interval. Cortical and corticomedullary signal curves were obtained from large concentric ROI's and the medullary curves were extracted by use of a peel off technique [3].

Curve fitting

Our curve fitting assumes that each total enhancement curve is the addition of four smooth functions. Each function has three parameters, describing its amplitude $\mu(i)$, peak time $\tau(i)$ and peak width $\lambda(i)$. The first three functions are gamma variates; the last one allows description of the tail of the curves. The fit is obtained using a Marquardt Levenberg algorithm [4]. For minimizing χ^2, 2000 iterations were allowed.

Fig 1 shows for a typical example case the experimentally obtained pair of cortical and medullary enhancement curves, each together with the fitted curve and its composing functions.
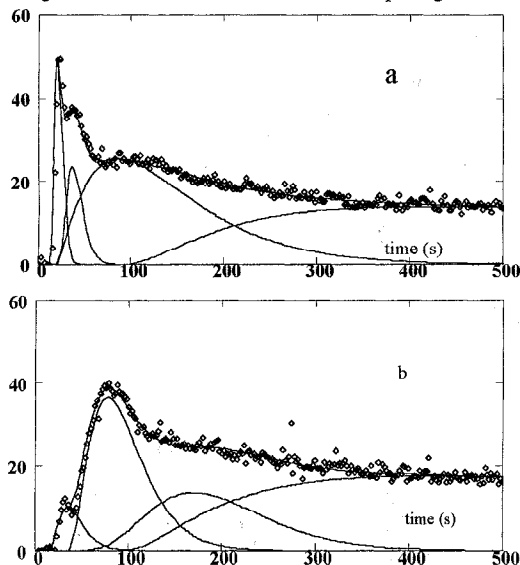

Fig 1. Cortical (a) and medullary (b) enhancement data, fitted curves and composing functions.

The fit to each cortical curve had 10, and that to each medullary curve 8 free parameters. Curve fits were obtained for each cortical and medullary enhancement curve and were repeated twice for each case, after selection of the ROI's by two readers.

Data analysis

The quality of fit was inspected by taking the ratio of the least square error of the residue between fit and data and the square of the noise in the data. The standard deviation of the obtained parameter values between readers (same patient, same session) and between sessions (same patient) was compared to that of the entire data set (between patients). Finally, for 3 cortical and 3 medullary data sets the 95% confidence limits were assessed for each separate parameter, assuming normal errors [4].

Results

Table 1 shows the mean values of the quality of fit, as defined above. The values indicate that, apart from the noise, the fitted curves could explain all features of the enhancement data.

	quality of fit (mean of all cases)
cortical data	1.20
corticomedullary data	1.22

Table 1. Mean quality of fit

Table 2 shows the variation coefficients (=sd/mean) of the obtained parameter values in 10 patients, 2 sessions per patient, 2 readers per session. The smallest values are found between readers. The values between sessions are larger. Note that his increase can in part be caused by session dependent kidney function. Between patients the variation coefficients have the largest values, suggesting that the parametric description validly displays differences in kidney function between patients.

	between readers	between sessions	between patients
cortex	0.02	0.09	0.22
medulla	0.03	0.11	0.29

Table 2. Mean variation coefficient per class of data.

Table 3 shows the 95% confidence intervals (mean of 3 cases) of all free parameters. Peak amplitudes μ and times τ are detected with reasonable (<50%) to good (<10%) accuracy, especially in the cortical data. Peak widths λ are not or not well detected.

	$\mu0$	$\tau0$	$\lambda0$	$\mu1$	$\tau1$	$\lambda1$	$\mu2$	$\tau2$	$\lambda2$	$\mu3$
cor	2	5	33	7	8	>100	5	3	>100	7
med	15	21	fixed	5	5	>100	13	5	fixed	47

Table 3. 95% confidence intervals of parameters (% of mean)

Conclusion.

Curve fitting of cortical as well as medullary enhancement data from dynamic MRI of renal transplants is possible.

References

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