Graphical Interpretation of Dynamic MR Perfusion Data

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Synopsis: Dependence of indices obtained graphically from the myocardial residue curve, on perfusion kinetics was investigated. Simulations were performed using the MMID4 model, combined with an input function derived from a clinical, peripheral bolus injection of Gd-DTPA. The initial upslope index is chiefly dependent on flow, but also depends on plasma volume. Indices obtained at peak enhancement had a complex dependence. The large effect-size of the delayed height parameter, and its single dependence on the volume of distribution, makes it a promising index.

Introduction: Magnetic resonance (MR) first-pass transit perfusion imaging combined with peripheral bolus-injection of extracellular agent Gd-DTPA has been widely investigated [1]. Although formal analysis methods based on agent kinetics have been reported [2-4], these methods have proven complex to implement and interpret, in clinical practice. We therefore sought to develop an efficient approach based on indices obtained graphically from the myocardial residue curve, and to relate these quantities to perfusion kinetic parameters.

Materials and Methods: ***Perfusion Model:*** Perfusion kinetic parameters, including mean plasma flow (Fp), capillary permeability-surface area product (PS), interstitial distribution volume (Vd), and plasma volume (Vp), were derived using the MMID4 model [3] (National Simulation Resource, University of Washington, Seattle). In our study, we used an input function derived from a region of interest (ROI) placed in the left ventricle (LV) cavity. The input data was fed into the model to yield myocardial residue curves. ***MR Imaging:*** MR imaging was performed on a 1.5 Eclipse (Philips Medical System, Cleveland Ohio, USA), using the Saturation-Inversion Recovery FAST sequence. Parameters were TR/TE/TI=4.2/1.5/150msec, with an image-section acquired every 1.3 sec, and for approximately 200 image-frames. Gd-DTPA (Magnevist) was injected via an ante-cubital vein (0.025 mmol/kg at 3 mL/s), for a healthy participant. LV cavity signal intensity (SI) was normalized according to; $SI = (SI_t - SI_o)/ SI_o$, where SI_t is the ROI mean SI at time, t, after Gd injection, and SI_o is the average of the mean SI of the baseline images. ***Simulation Experiments:*** Baseline kinetic parameters were chosen to approximate known normal human myocardial values, namely; Fp=1.0 ml/min/g, PS=0.5 ml/min/g, Vd=0.3 ml/g, and Vp=0.04 ml/g. We systematically varied a single parameter. We chose a convenient parameter-change step of 50%, keeping in mind that myocardial data is often confounded by respiratory-related irreproducibility of order 20%. Indices determined graphically from the myocardial residue curves included; initial up-slope, peak amplitude, time to peak amplitude, and delayed height, evaluated at approximately 2 mins after the end of contrast agent infusion. The % change for each of the graphical indices was defined as; % CHANGE=Δ Index, normalized to its reference value, in response to modifying individual physiological parameters by 50%. Two permeability states were assessed corresponding to normal flow and to low flow.

Results: Table 1 summarizes the estimated % change of the graphical indices (initial up-slope, peak amplitude, time to peak, and delayed height) for each of the perfusion kinetic parameters (Fp, PS, Vd and Vp). The observed graphical changes, obtained by modifying the kinetic parameters, are also plotted (Fig 2.). Examination of the physiological dependence of several indices that have gained some attention in myocardial perfusion analysis is instructive. The initial upslope is chiefly dependent on flow, however there was an important contribution of plasma volume. Indices obtained at peak signal change (peak amplitude and time to peak) had the most complex physiological dependence, with a contribution from volume of distribution, but also depending on flow and permeability. The delayed height index manifested an overwhelming influence of volume of distribution, with contributions from the other kinetic parameters being well below the physiological noise limit, that has been reported. It is also interesting to note that this height index manifested an effect that was a factor of 3 greater than the putative normal physiological variation, and is thus a promising candidate for the reliable indexing of perfusion data.

Conclusions: The initial upslope has gained favour as an index of perfusion kinetics. However, due to its observed dependence on a single kinetic parameter (volume of distribution), and its robustness (~3 times physiological noise), in our simulation experiments, the delayed height also warrants further study as a graphical indicator of perfusion kinetics.

Table1— Measurements of the % change of the graphical indices.

	% Change			
	Upslope	**Peak**	**Time to Peak**	**Delay Height**
Fp ↓ 50%	- 36.8	-9.1	21.1	5.4
Vp ↓ 50%	-18.8	-4.8	0.0	-3.8
Vd ↑ 50%	1.5	22.6	35.7	65.5
PS ↑ 50% /NF	8.9	14.8	-10.5	3.6
PS ↑ 50% /LF	0.0	5.8	-2.1	5.2

Table legends: Fp: plasma flow. Vd: interstitial distribution volume. Vp: plasma volume. PS: permeability-surface area product. NF: normal flow of 1.0 ml/min/g. LF: low flow of 0.1 ml/min/g. Negative numbers refer to a decrease, while positive numbers refer to an increase.

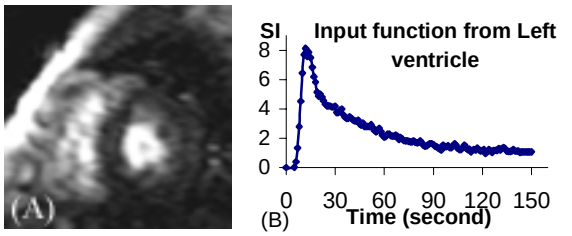

Fig.1—First-pass myocardial perfusion MR image of a patient (A), and the input function from the left ventricle cavity (B).

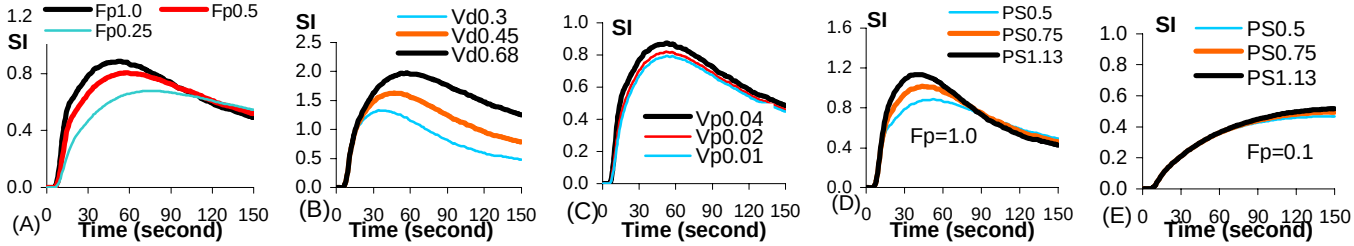

Fig.2—The influence of each of Fp (A), Vd (B), Vp (C), PS at normal flow (D), and PS at low flow (E), on the graphed myocardial residue curve is manifest.

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