Myocardial T1 During Multiple Bolus Injections

C. Stehning[1], T. Lockie[2], E. Nagel[3], M. Ishida[3], and S. Plein[3]
[1]Philips Research Europe, Hamburg, Germany, [2]Cardiovascular Division, King's College, London, United Kingdom, [3]Division of Imaging Sciences, King's College, London, United Kingdom

Introduction

MR first pass perfusion imaging has become a valuable clinical tool for the assessment of myocardial perfusion [1]. The increased spin-lattice relaxation rate 1/T1 and dynamic signal enhancement following the intravenous injection of Gd-DTPA was shown [2] to be a linear function of the local gadolinium concentration. However, studies in rat myocardium [3] revealed that the enhancement may reach a plateau, which would inhibit the deduction of reliable kinetics from observed signal intensity-time curves. The aim of the present study was to investigate whether such a saturation effect has to be taken into account in MR-based perfusion studies involving multiple injections of Gd-DTPA. The myocardial T1 values were measured at multiple points in time during the study and compared with a reference, i.e. the expected T1 extrapolated from the previously published [4] washout kinetic tables of Gd-DTPA following a single injection.

Methods

All experiments were performed on a clinical 3T scanner (Achieva, Philips Healthcare) equipped with a 32 element cardiac coil array. Experiments were conducted in 10 healthy adult volunteers with no history of heart disease and no cardiovascular risk factors. In order to resemble clinical practice and to optimize sequence timing, 1-2 injections of a low concentration (10% dilute) prebolus were given (#0, 0.025mMol/kg). Three subsequent contrast injections (#1 - #3, dose=0.25 mMol/kg body weight of Magnevist, Bayer Schering, Germany) were given at an approximate temporal spacing of 15 mins, and a fourth injection (#4, 0.25mMol/kg) was given immediately after the third. Myocardial T1 was measured before the respective contrast injections using an ECG-triggered "Look Locker" [5] inversion recovery sequence. The scan parameters were as follows: FOV=300x300mm², measured voxel size=2.5x2.16x10mm³, inversion-prepared T1 weighted FFE-EPI, flip=10°, EPI factor=3, 9 excitations per phase, 16 phases distributed over 2 RR intervals (phase interval 100ms). One pause interval was employed in between inversion pulses to allow for magnetization recovery. The total scan duration was one breathhold (9 RR intervals). T1 was measured in a ROI in the septum wall (position adjusted in each phase to cope with cardiac motion). T1 values were calculated using a plugin tool comprising a 3-parameter exponential fit with Look-Locker correction [6] implemented in an open source DICOM viewer (www.osirix-viewer.com). The measured T1 values were compared with the expected values extrapolated from the previously published Gd-DTPA concentrations found in blood serum [4] after intravenous contrast injection, where a fixed blood volume fraction in myocardium and equal relaxivities of Gd-DTPA in blood and myocardium were assumed. The molar concentration of contrast agent in blood was assumed to be a linear addition of the existing concentration at the given delay from the previous injection, and the actually injected dose.

Results and Discussion

The T1 values measured prior to the respective contrast injections are summarized for all volunteers in table 1. A minor decrease in myocardial T1 was observed after the injection of the 0.025mMol/kg dilute. A marked decrease of myocardial T1 was observed following all 0.25mMol/kg injections. A saturation effect, i.e. a plateau of T1 after subsequent injections, could not be observed at the given doses. A moderate variance was observed for some T1 values, which can in part be attributed to the slight variations in time at which the values were measured. A plot of the measured myocardial T1 versus the expected values obtained from the previously described model is shown for one volunteer in Fig. 1. The timing and given doses were taken into account for the calculation of the T1 model (solid arrows). A good agreement between the expected and measured values was observed.

Table 1 Summary of measured T1 values (mean and stdev over all volunteers)

injection no.	T1 [ms]	stdev
baseline T1	971 ±	73
after 0.025mMol/kg (#0)	950 ±	105
after 0.25mMol/kg (#1)	833 ±	47
after 0.25mMol/kg (#2)	787 ±	33
after 0.25mMol/kg (#3)	728 ±	33
after 0.25mMol/kg (#4)	552 ±	58

Conclusion

For the doses employed in the present study, no plateau of myocardial T1 could be observed after subsequent contrast injections. A decrease of T1 was observed following each individual 0.25mMol/kg injection, which indicates that contrast-enhanced perfusion studies can be conducted with multiple contrast injections. The measured myocardial T1 correlates well with the expected values extrapolated from the excretion characteristics of Gd-DTPA [4]. Although the currently available data points are relatively sparse, is seems that the contrast kinetics in myocardium after multiple injections can be modeled with sufficient accuracy using a simple superposition of the logarithmic contrast washout behavior [4]. According to the model, an oscillation around an equilibrium T1 value, which is determined by the individual dose, injection interval, and excretion rate, could be expected if further contrast injections were given. In conclusion, we suggest that perfusion studies can be conducted with multiple contrast injections, and myocardial T1 can be approximated from a model with sufficient accuracy to translate signal intensities into contrast agent concentrations.

References [1] Wilke N et al., JMRI (1999) [2] Strich G et al, Radiology (1985) [3] Tweedle MF et al., Magn Reson Med. (1991) [4] Weinmann et al, AJR (1984) [5] Look DR et al Rev. Sci. Instrum (1970) [6] Deichmann R et al, J Magn Reson (1992)

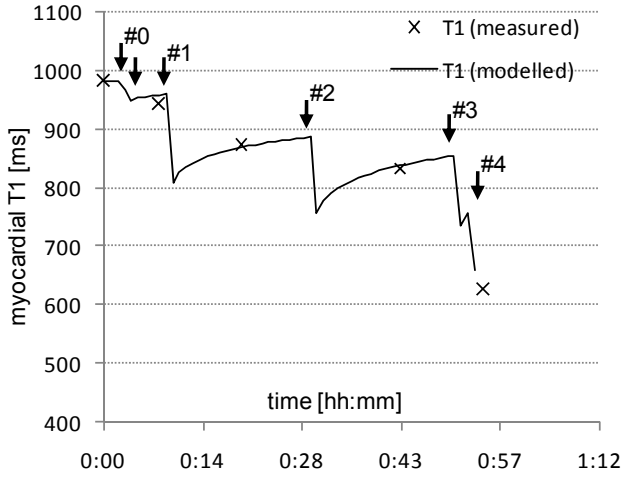

Fig. 1 Plot of measured (cross) myocardial T1 versus the expected values extrapolated from previously published contrast washout kinetics. A good agreement between the model and the measured values was observed.