MR Myocardial Perfusion Imaging at 3T: A Comparison with 1.5 T

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Introduction: Myocardial perfusion imaging is considered one of the more compelling applications for cardiac MRI at 3T, although evidence is currently sparse on the improvements that can be achieved, compared to 1.5 T. The accuracy of assessing myocardial perfusion with MRI depends on contrast-to-noise, peak contrast enhancement (CE), and the absence of image artifacts that could otherwise be confounded with perfusion defects. The goal of this study was to optimize myocardial perfusion imaging at 3T, and compare its performance at 3 Tesla to an analogous technique used at 1.5 Tesla, both by MRI studies in volunteers, and numerical simulations.

Methods: Myocardial perfusion imaging was performed at 3 T (Philips Intera) in 6 volunteers and 1 patient with gradient echo-sequences, with either a single spoiled gradient echo (TR/TE/flip angle = 2.4 ms/1.1 ms/18˚ and parallel image acquisition with SENSE speed-up of x2), or with a short echo train (TR/TE/flip angle =7.6 ms/3.4 ms/20˚) after each radio-frequency excitation pulse. A bolus of Gd-DTPA contrast agent (0.025-0.06 mmol/kg at 3T, and 0.04 mmol/kg at 1.5T) was administered with a power-injector. Measurements of T_1 in myocardium were performed before contrast administration with a breath-hold Look-Locker technique, with non-slice-selective preparatory inversion pulse after the R-wave, and read-out of k-space segments during the inversion recovery over 20 cardiac phases (~50 ms/cardiac phase). At 1.5 Tesla (Siemens Sonata) the gradient-echo perfusion imaging sequence (TR/TE/flip angle = 2.2 ms/1.2 m/18˚/ without parallel acquisition) used the same pulse sequence technique, with only minor deviations of the sequence parameters from the settings used at 3T. T1 measurements were performed at 1.5 T with a breath-hold Look-Locker technique with steady state free precession. A phased array torso coil was used for studies at 1.5 T and 3 T. The effective T1 values were corrected for the sequence-specific perturbation of the inversion recovery, using previously validated approaches. For the perfusion studies, peak contrast contrast enhancement (pCE) during the first pass was calculated from the signal intensities (SI) as [peak SI – SI(pre-CE)]/SI(pre-CE). Contrast-to-noise (C:N) was defined as baseline-corrected peak signal during CE, divided by the standard deviation of the baseline SI (i.e. before contrast arrival).

Simulations of the first pass signal time course were based on step-wise solutions of the Bloch equations to model the longitudinal and transverse magnetization dynamics measured with a T_1-turbo-FLASH gradient echo imaging sequence with a saturation-recovery magnetization preparation. The exact parameter values used for MR imaging at 1.5 T and 3.0 T were duplicated for the simulations. T_1 relaxivity for Gd-DTPA was set to r1= 4.6 mM^{-1} sec^{-1} for 1.5 T, and r1=4.1 mM^{-1} sec^{-1} for 3.0 T, corresponding to values measured in saline solutions of Gd-DTPA.

Results: At 3T, perfusion studies in 2 volunteers with an echo train length of 3 showed marked appearance of artifacts at the sub-endocardial border during the wash-in of contrast into the LV cavity. Perfusion studies with a single echo acquisition showed no such artifacts at 3 T, as can be seen in figure 1 with images during consecutive phases of bolus transit. At 1.5 Tesla, myocardial T1 values, measured in 22 volunteers, averaged (mean ± SD) 604 ± 198 ms. At 3 Tesla, analogous measurements in 6 volunteers yielded T1= 936 ± 107 ms. The results of simulations showed that the pCE for a contrast bolus shape with a peak concentration of 0.35 mM/L, and using the mean values for pre-contrast T1's measured in volunteers at 1.5 and 3 T, were ~85% and 136%, respectively. The ratio of pCE for 3T and 1.5 T of 1.6:1 is in reasonable agreement with the pCE's observed in volunteers, shown in figure 2. C:N at 1.5 T with a 0.04 mmol/kg bolus averaged 19 ± 10 (min. C/N: 3:1; N=12 volunteers) without parallel imaging. At 3T with a 0.03 mmol/kg bolus C:N averaged 25±11 (min. C:N=8:1; N=4 volunteers) with parallel imaging, and a SENSE speed-up factor of 2.

Conclusions: The results of studies in volunteers and simulations show that the higher pre-contrast myocardial T1 at 3 T leads to more pronounced contrast enhancement than at 1.5 T. T1 in myocardium was ~30% higher at 3T, compared to 1.5 T, and this difference accounts for the higher pCE at 3T, while a lower T_1 relaxivity at 3 T appears to have only a very minor effect on the observed contrast enhancement**.** The higher C:N at 3T can be used for speed-up of the image acquisition with parallel imaging techniques and/or better spatial resolution, both of which have a positive impact on the (quantitative) assessment of myocardial perfusion.

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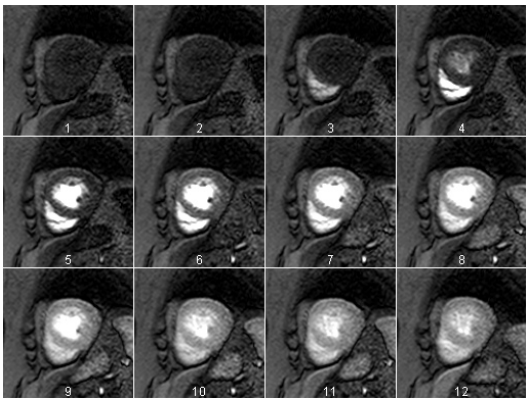

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