The Relationship Between Signal Intensity and Myocardial Gadolinium Concentration for Three MR Perfusion Pulse Sequences: Implications for Measuring Absolute Myocardial Blood Flow

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Background:

Absolute myocardial blood flow (in ml/min/g) can be calculated from CMR first-pass perfusion studies by model-based deconvolution of the left ventricular blood pool and myocardial signal intensity-time curves. A basic assumption of the deconvolution technique is that signal intensity (SI) is proportional to gadolinium concentration [Gd] in both the blood pool and myocardium. Dual-bolus and dual-echo techniques have been proposed to address the known nonlinear signal response of the blood pool to gadolinium. Based on signal response to escalating bolus injections of gadolinium in volunteers, recent reports suggest that despite its low signal, the myocardial SI response to [Gd] is also nonlinear. The myocardial SI response to myocardial [Gd] needs to be defined for common perfusion pulse sequences to guide the appropriate application of absolute perfusion measurements by deconvolution.

Purpose:

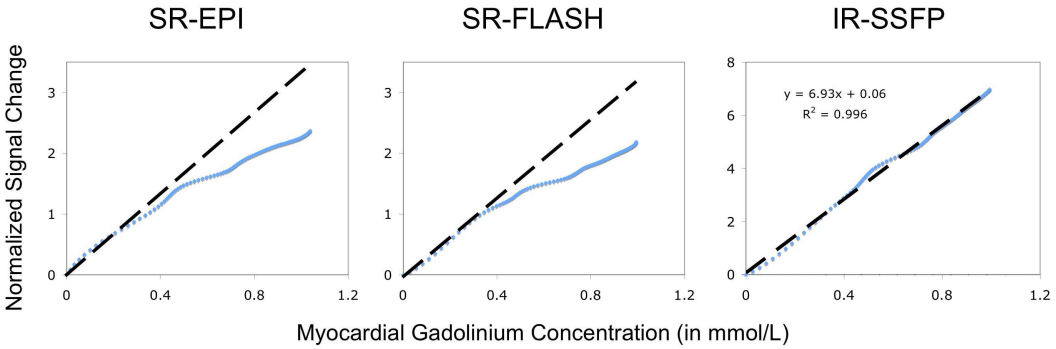
We sought to define the relationship between myocardial SI and myocardial [Gd] for three pulse sequences: 1) saturation recovery-prepared segmented echo-planar-imaging (SR-EPI), 2) saturation recovery-prepared turbo fast low-angle shot (SR-FLASH), and 3) inversion recovery-prepared single-shot steady-state free-precession (IR-SSFP).

Methods:

Imaging was performed in two purpose-bred hounds, chronically instrumented with left atrial, right atrial, and aortic catheters on a 1.5 T clinical MR scanner (Siemens Sonata). Cardiac T1 was measured from T1 mapping performed using a modified Look-Locker technique (MOLLI). Regional gadolinium concentration was calculated from the longitudinal relaxation rate (1/T1). During a constant slow infusion of Gd, a single mid-ventricular short axis slice was alternately imaged for 1) signal intensity by SR-EPI, SR-FLASH, or IR-SSFP and 2) T1 mapping (MOLLI). Infusion experiments were performed with an infusion rate of 0.5 mmol/min in order to span the myocardial signal range expected in response to a 0.05 mmol/kg IV bolus. SI values were normalized to correct for coil inhomogeneity and the baseline signal. The increase in normalized SI and [Gd] were plotted against the time of infusion. The SI and [Gd] curves as functions of time were interpolated using a cubic spline technique to generate a parameterized SI response curve as a function of [Gd].

Results:

The relationship between SI and [Gd] was nonlinear for SR-EPI and SR-FLASH, resulting in underestimation of [Gd] higher than 0.5 mmol/L. IR-SSFP was linear over the full range of [Gd] tested. At a [Gd] of 1 mmol/L, the relative SI increase over baseline for SR-EPI, SR-FLASH, and IR-SSFP were 2.4, 2.2, and 7.0 respectively. Figure 1 illustrates the signal response for each pulse sequence.



Conclusions:

The relationship between myocardial SI and [Gd] depends on the first-pass perfusion pulse sequence used. IR-SSFP demonstrates excellent myocardial signal enhancement and is linear over the range expected for a 0.05 mmol/kg bolus. Over the same range, SR-EPI and SR-FLASH exhibit less robust myocardial signal enhancement and a nonlinear response to [Gd]. The nonlinear signal response of SR-EPI and SR-FLASH needs to be accounted for to avoid underestimation of absolute myocardial blood flow by model-based deconvolution.