In-flow Effects in Determination of Arterial Input Functions

L. Axel[1], D. Kim[1]
[1]Radiology, NYU Medical Center, New York, NY, United States

Introduction

Studies of dynamic contrast enhancement of tissue in MRI require an accurate measurement of the arterial input function, in order to correct for the effects of possibly varying delivery of the contrast to the tissue. If images of a large artery or the left ventricle (LV) cavity are included in the image, the blood signal there can be used to approximate the arterial signal supplying the tissue. However, the motion of the blood through the imaging plane may affect the signal, as has been known since the early days of MRI. This effect has been previously demonstrated but not analyzed [1]. We sought to investigate the magnitude of this effect in the context of a representative application, studies of myocardial perfusion with first-pass contrast enhancement.

Methods

We acquired T1-weighted images using a saturation-recovery (SR) TurboFLASH sequence to monitor contrast enhancement; additional proton density (PD) images were acquired to correct for regional image non-uniformity and to scale the observed intensity to the intensity corresponding to equilibrium magnetization. The effects of blood through-plane motion on the saturation produced by the imaging excitations themselves were modeled and compared against observations under different imaging conditions.

Modeling- Blood traveling through the imaged slice at a velocity, v, less than the critical velocity, v_c, needed to wash out the slice between imaging excitations (given by the ratio of slice thickness to TR) will retain some saturation due to prior excitations, in addition to the saturation from the initial saturation pulse; the magnitude of this effect will depend on the flip angle, α, the ratio of TR to T1, and the ratio of v to v_c. For TR<<T1 and v= v_c /n, the signal will be reduced by a factor of approximately $(1+\cos\alpha+\ldots+\cos^{n-1}\alpha)/n$; for shorter T1, this saturation effect will be reduced.

Experiments- A normal volunteer was scanned on a 1.5T Siemens Avanto system. After bolus injection of 12ml of 0.5M Gd contrast agent (Magnevist, Berlex) at 6 ml/s followed by a saline flush, repeated T1-weighted image acquisition was performed in suspended respiration at 3 levels (aortic root, and LV short axis at base and mid-ventricle) per heart beat, for 40 heart beats, using a non-selective BIR4 saturation pulse, followed by TurboFLASH imaging with image matrix 192x64, FOV 400x267 mm, TR=2.6ms, TE=1.2ms, slice thickness=8mm, and GRAPPA parallel imaging (R =2). Total image data acquisition time per slice was 115ms. Two imaging series with different flip angles, 8º and 16º, were obtained, with 20 minutes delay between injections. Separate PD imaging for calibration was performed at the same locations, with no saturation pulse and with a flip angle of 3º, with an average of 10 repeated acquisitions to increase the signal-to-noise ratio (SNR). Phase-contrast imaging determination of through-plane velocity was performed at corresponding levels. The T1-weighted images were normalized by the PD images and scaled for flip angle, and regions of interest (ROI) were drawn in the aortic root, the descending aorta, and in the LV cavity for measurement of intensity and velocity.

Results

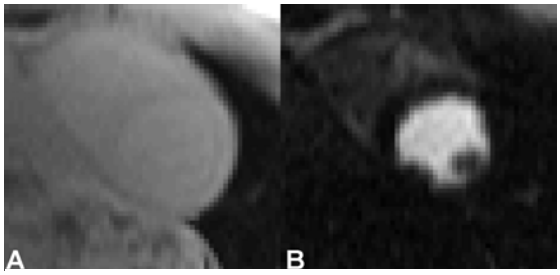

Fig.1. Representative PD (left) and T1-weighted (right) images.

The average through-plane velocities at the times of imaging in the aortic root (AA), descending aorta (DA), LV base (LVB) and LV mid (LVM) locations were 44, 66, 47 and 19 cm/s, respectively. Representative PD and SR contrast-enhanced images are shown in Fig. 1. Representative normalized data curves for the four ROIs are shown in Fig. 2. For the experimental parameters and measured velocities, the model predicts relative drop in signal from 8º to 16º flip angles of 8%, 5%, 8% and 11% for AA, DA, LVB, and LVM, respectively. The corresponding measured drop in signal for the two flip angles, at the peak enhancement of the blood, was 8%, 5%, 9%, and 14%.

Discussion

Normalization of the T1-weighted signal by the PD yielded signal dependence on imaging parameters consistent with the theoretical model. To minimize the effects of incomplete wash-out on in-flow effects on the signal used for determination of arterial input function from MR images, we must make appropriate choices of slice location, cardiac cycle phase timing, TR, flip angle, and slice thickness. A location (and cardiac cycle phase) with high through-plane velocity is preferable. TR is typically chosen to be as small as practical, which limits the ability to control the contribution of this factor. While flip angle and slice thickness should ideally be minimized to reduce their contribution, too small a flip angle or thin a slice will reduce SNR.

References: 1. Ivancevic MK, et al. Magn Reson Med 50:885-891 (2003).

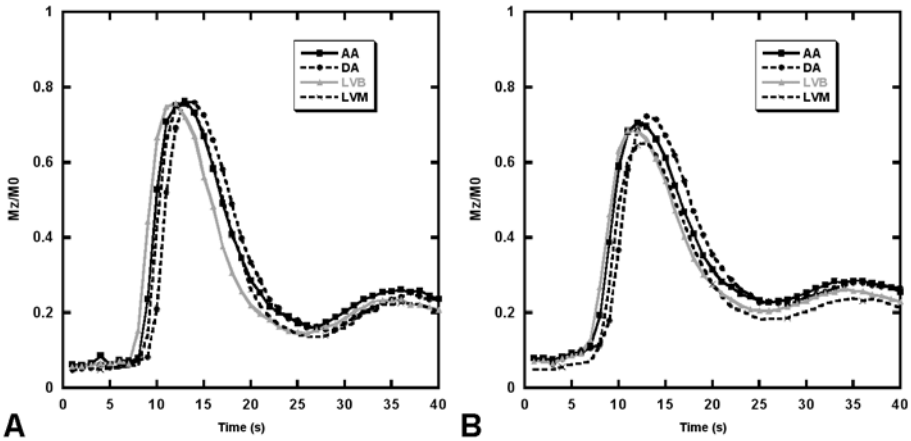

Fig.2. Normalized signal-time curves for 8 º (left) and 16 º (right).