AIF Correction for Non-Uniform k-space Data Weighting Effects in First-Pass Cardiac Perfusion MRI

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Introduction: To obtain first-pass cardiac perfusion images, a saturation-recovery (SR) preparation with TurboFLASH readout can be used to capture the contrast enhancement dynamics. However, when using a SR preparation, non-uniform k-space data weighting in the phase-encoding direction, due to data acquisition during the transition toward the steady state, can lead to a filtering effect. This may lead to systematic overestimation of the image-derived arterial input function (AIF), with a resulting bias in the perfusion calculations. In this work, numerical simulations were used to correct for non-uniform k-space data weighting effects on the AIF.

Method: A SR TurboFLASH imaging sequence with centric k-space reordering was implemented on a 3T MR scanner (Tim Trio; Siemens). Image parameters included: slice thickness = 8mm, TE/TR = 1.2/2.4ms, TD = 50ms, flip angle = 10°, and receiver bandwidth = 1008Hz/pixel. A proton density-weighted (PDw) image was also acquired for normalization [1]. Three water phantoms with different concentrations of Gd-DTPA and six healthy volunteers (29±12 years old) were tested; in vivo, the AIF measurements were performed at the aortic root. The Ti values were calculated using a single-point Ti method [1,2]. For the phantom, a reference Ti value was calculated from a multi-point spin-echo inversion recovery method [3]. For signal correction, a numerical model of each object geometry was generated and the corresponding k-space data-weighting filters for the Ti-weighted (Tiw) and PDw images were calculated using the Bloch equations with the same imaging parameters and k-space trajectory used in MR imaging (Fig. 1). Using the numerical simulations, for the phantoms, a fitting algorithm was used to correct the Ti values and for the in vivo data, the MR signals were corrected using a look-up table, including a pair of signals simulated with and without non-uniform k-space data weighting filters.

Results: As seen in Fig. 2, the profiles of the normalized MR signals and the simulated signals of the phantoms showed excellent agreement. For the phantoms 1-3, the Ti values calculated directly from the single-point method were 26.5ms, 83.5ms and 434.8ms, and the corresponding % errors with the reference Ti values (33ms, 100ms, 507ms) were 19.5%, 16.5% and 14.7%, respectively. The Ti values from the fitting procedure, using the simulated model, were 33.3ms, 99.2ms and 507ms and the corresponding % errors were 0.9%, 0.8% and 0.5%, respectively. For in vivo data, a look-up table was calculated as shown in Fig. 3A and was used to correct the observed MR signals (Fig. 3B). The average absolute percent differences of the observed and corrected signals for all subjects was 18.4% ± 5.7%.

Discussion: This new method allows numerical correction for the effects of non-uniform k-space data weighting on Tiw signals acquired using a SR TurboFLASH imaging sequence with centric k-space ordering. Using a look-up table approach, the observed signals can be corrected easily and rapidly, and the corrected signals can be used as more accurate inputs for tracer kinetics modeling.