Fast Frequency Selective Keyhole MRI

J. Medič*, S. Tomažič*, I. Serša†, F. Demsar†
*University of Ljubljana, †J. Stefan Institute, Ljubljana Slovenia

Introduction

The conventional keyhole data acquisition is used to permit faster imaging procedures without loss of sensitivity in dynamic studies, where initial high-resolution spatial information is combined with low-resolution spatial information at later points in time. We propose a new Fast keyhole (FK) method, which allows dynamic acquisition of a low-resolution image signal from selected most relevant or arbitrarily chosen k-space points and reduces acquisition time of conventional keyhole approach and eliminates artifacts due to off resonance sources. The effect of the FK method on contrast in MRI is evaluated.

The Fast keyhole method is based on the same principle as echo planar imaging (EPI). This includes single signal excitation, which is followed by signal acquisition while switching magnetic field (MF) gradients. The main difference between EPI and FK is in the gradient part.

Complete k-space data set is acquired only once before the administration of contrast agent. The N k-space points with highest absolute values, which contribute most to the image, are determined from the pre-contrast image in k-space. They represents key window that is used to acquire a signal latter in dynamic process. After selection of k-space points, trajectory and corresponding gradient sequences are calculated. In the next step a frequency selective subset of k-space trajectories (filtering) is designed. This is done by shifting the calculated k-space trajectory L times by H points in the 2nd acquisition, 2H points in 3rd acquisition, etc. Acquired subset is then summed up into one dynamic key image, combined with pre-contrast image and Fourier transformed for the production of subsequent keyhole images.

Figure 1: Fast keyhole Images obtained with a) single acquisition (L = 1) and b) filtering procedure (L = 4, H = 8)

Material and Methods

MR Imaging was performed on a Bruker Aspect 3000, operating at 100 MHz with micro imaging equipment and FOV=50 mm. Tubes were filled with water (Δfwater = 0), oil (ΔfOil = 320Hz), and Gd-DTPA (ΔfGd = 0Hz) respectively. Due to limitations of gradient amplifiers, sampling time Δt was set to 20μs and instead of a single excitation sequence with N gradient pulses, two excitations were implemented with TR = 300ms. The experiment started with the tube filled with water. Later Gd-DTPA was administrated at one minute intervals (Fig. 2).

Results and Discussion

The results obtained by simulations as well as on dynamic enhanced MRI, show that the quality of the keyhole image depends on selection of k-space points and selected trajectory. For selected N = 768 most relevant k-space points acquisition time is 153ms and resolution is comparable to conventional keyhole approach with \( t_{acq} = 15s \). In the presence of oil, the image acquired by linear trajectory (like EPI) is blurred (Fig. 1a). In the next experiment filtering procedure were implemented on the same k space data. Trajectory was shifted four times with H = 8. Fig. 1b. shows that blurring is completely removed. Same experiment was applied to different trajectories and in all cases the oil tube is completely removed from the image. The number of required shiftings depends on maximum off resonance frequency of the observed object and selected k-space trajectory.

Figure 2: Time-intensity curve obtained after administration of contrast agent with error bars that represent image noise (σerr).

Quantitative analysis of contrast agent uptake showed that number of required k-space points \( (N) \) depends on object size like in conventional keyhole MRI [2] and ROI. Fig. 2 shows results obtained with ROI equal to object size (7mm). While the maximum number \( M \) of k-space points for one acquisition is determined by \( \Delta t \) and \( T_R \). If \( M < N \), more excitation are needed, which increase acquisition time to \( S \cdot T_R \) but also improves quantitative analysis.

Conclusions

The main advantage of the fast keyhole imaging compared to the standard keyhole MRI is in much higher imaging speed. Artifacts due to off resonance sources are greatly reduced by the filtering procedure, which can be also implemented on all single shot MRI methods. Experimental data on our Gd-DTPA contrast enhanced dynamic MR images, show that quantitative analysis give results comparable to those obtained by conventional keyhole MRI. Furthermore the technique can be easily implemented for clinical use.

References