An Interactive Real Time Sequence for Interventional MRI

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Introduction

In interventional MRI, the imaging sequence has to perform many tasks. The sequence has to be fast enough to provide high frame rates with reasonable image contrast. For device tracking, the scan plane position and orientation must be adaptable in real time. The signal intensity of receiver coils should be scalable in the MR images to optimize visualization of active devices. The image contrast should be suited for the desired intervention, and the sequence should support automatic slice positioning if position information of devices is available. In this study, we developed an interactive real time software package for use on a clinical 1.5 T scanner (Magnetom Avanto and Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany). We tested the feasibility to a) improve workflow in cardiac studies in volunteers, b) detect contrast agent in phantoms, and c) perform MRI-guided cardiac catheterization in swine.

Material and Methods

An interactive gradient echo sequence was implemented that supports cartesian and radial *k* space trajectories and real time reconstruction. For radial trajectories, a sliding window reconstruction and a fast regridding algorithm [1] was applied. Slice position and orientation could be changed in real time using the standard user interface of the scanner.

a) Volunteer Study: The sequence was used to acquire cardiac localizers of a healthy volunteer in real time to obtain a quick overview of the anatomy (TE/TR = 1.84 ms/3.67 ms, 128 matrix, 33 projections per image). The sequence could be paused to enable communication and give short breath hold commands.

b) Phantom Study: The sequence allowed image contrast to be changed in real time from trueFISP to FLASH. The T2/T1 contrast of a trueFISP sequence was well suited for intravascular interventions [2], whereas a T1-weighted FLASH sequence can be used for visualization of contrast agent [3]. A weak *z*-gradient-dephaser can be applied to enhance the contrast-background ratio [4] in contrast enhanced studies using projection images. In a phantom study, the optimum *z*-dephaser amplitude was determined (syringe filled with diluted contrast agent (1:40, Magnevist, Schering AG, Berlin, Germany) in water, FLASH, α/TE/TR = 60°/ 2.1ms / 4.2 ms, GRAPPA 2, 88x256 matrix, 6/8 partial Fourier reconstruction, 80 mm slice). A nonselective saturation recovery pulse could be optionally applied prior each image to improve background suppression.

Furthermore, optional acquired projection data sets between two consecutive images could be used for continuously updating the slice position and orientation in real time [5]. The tip position and orientation of devices were determined by measuring the hyper-intensive MR signal surrounding small receiver coils attached to a device.

c) Animal Study: An active guidewire (Intercept, SurgiVision, Inc., North Chelmsford, MA) was percutaneously inserted into the femoral artery of a domestic pig and advanced to the ascending aorta [6]. The image intensity of the receiver coil and image orientation was adjusted in real time to optimize device visualization (trueFISP, slice thickness = 12 mm) in the MR images. A 6-French catheter was used to engage the left ventricle and left coronary artery. A small bolus of contrast agent (Magnevist, 3 ml, 3 ml/s injection rate) was injected to visualize the coronary arteries using the FLASH sequence with the *z*-dephaser.

Results

a) Volunteer Study: It was possible to interactively obtain localizer images in all primary cardiac views in < 1 minute (Fig. 1a-b, frame rate: 8.25 fps) without stopping the scan. Only selected images were saved into the data base and these were automatically loaded into the viewer for further scan plane planning.

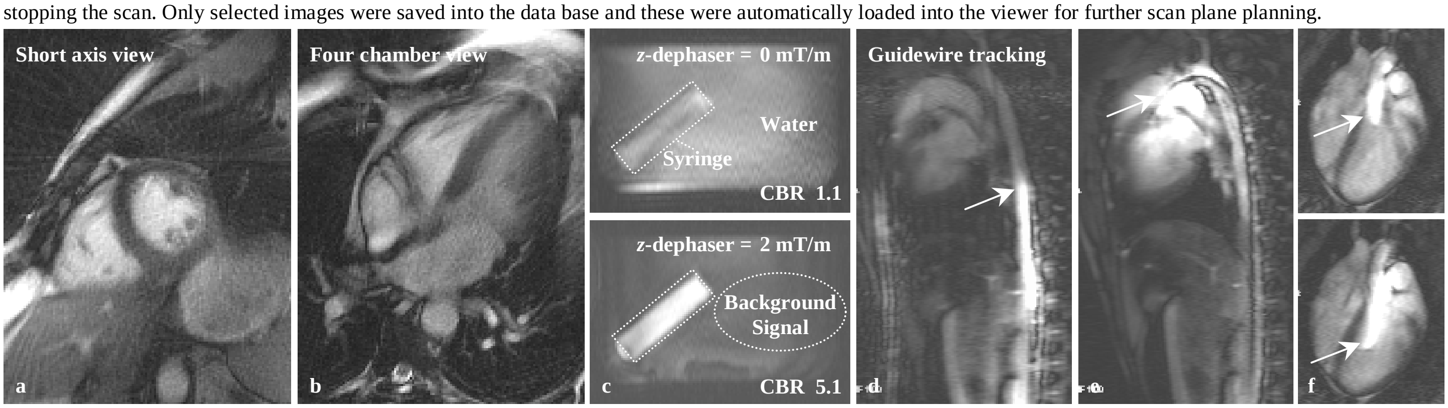

Fig. 1: a-b: *Radial cardiac localizers acquired in a human volunteer with the interactive real time sequence (frame rate 8.25 fps).* c: *Phantom study to demonstrate the background suppression in contrast enhanced projection images using the z-dephaser technique: The background was suppressed efficiently and the contrast to background ratio (CBR) was maximized.* d-f: *Animal study: Tracking of an active guidewire from the abdominal aorta to the heart in a sagital and coronal view (7 fps).*

b) Phantom Study: Background signal in the projection images was suppressed efficiently using the *z*-dephaser technique. The contrast to background ratio (CBR) was maximized (5.1 vs. 1.1) for a *z*-dephaser amplitude of 2 mT/m (Fig 1c). For higher amplitudes, images were inhomogeneous. The automatic slice positioning was evaluated with small receiver coils. The slice position was shifted to reflect the position of one coil, and the slice orientation was set using two coils (normal vector) or three coils (plane definition), and the new position was reflected in the standard user interface of the scanner. The failure rate was < 5%.

c) Animal Study: Visualization of the active guidewire occurred at a frame rate of 7 fps. Real time adjustment of the signal intensity of the guidewire and image position was used to track the guidewire-catheter system successfully from the abdominal aorta into the heart (Fig 1d-f, tip of the guidewire indicated by arrowheads).

Discussion

a) Volunteer Study: The interactive sequence could be used to find cardiac orientations (e.g. for coronary artery imaging) or monitoring of wall motion in stress studies.
b) Phantom Study: The *z*-dephaser technique has been useful for a MR-guided renal embolization [7]. An advanced magnetization preparation scheme has been developed for coronary artery visualization [8] and will be implemented in the software package. Automatic slice positioning remains to be evaluated in animal studies.
c) Animal Study: Real-time device visualization was reliable. The sequence might be well suited for other MRI-guided endovascular applications.

References

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