trueFISP MRI with Active Catheter Tracking and Real-Time Parallel Image Reconstruction

S. Müller[1], M. Bock[1], C. Fink[2], S. Zühlsdorff[3], P. Speier[4], W. Semmler[1]
[1]Medical Physics in Radiology, German Cancer Research Center, Heidelberg, Germany, [2]Radiology, German Cancer Research Center, Heidelberg, Germany, [3]MR Research and Development, Siemens Medical Solutions, Chicago, Illinois, United States, [4]MR Research and Development, Siemens Medical Solutions, Erlangen, Germany

Introduction

In intravascular procedures such as stent placement or embolisation instruments are introduced into blood vessels. The motion of the instruments is conventionally monitored with X-ray techniques such as digital subtraction angiography, however, MR-guidance with real-time imaging has recently been shown to offer several advantages as e.g. excellent soft tissue contrast and cross-sectional imaging.

When combined with active MR tracking, the instruments can be localized during the intervention at high frame rates [1]. Unfortunately, image frame rates are typically below 4 images/s with cartesian k-space sampling. In this work parallel image acquisition techniques with real-time reconstruction are utilized to increase the image frame rates by approximately a factor of two. The tracking pulse sequence was evaluated in an animal experiment.

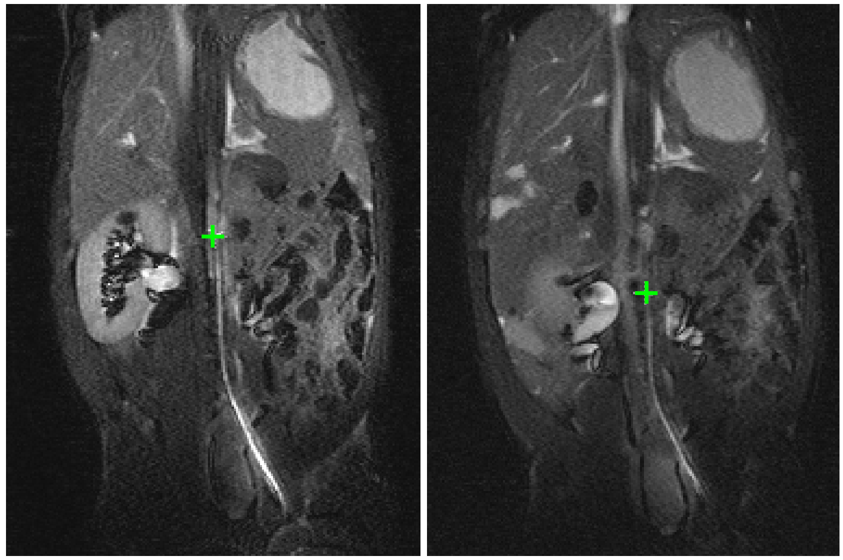

Fig. 1: Real-time interactive catheter tracking images with (left) and without (right) parallel imaging. The active catheter tip is shown as a green cross.

Materials and Methods

MR-guided interventions with parallel MRI have several unique problems that are not present in conventional parallel MRI. During the course of the intervention position and orientation of the imaging slice is continuously changing. Unfortunately, the sensitivities of the individual receiver coils need to be known for each slice position orientation, which requires an acquisition technique with an auto-calibration method (e.g. GRAPPA [2]). For arbitrary slice orientations a sufficient amount of spatially non-overlapping rf coil sensitivities must be available to separate the individual signals. This is guaranteed by using a minimum number of rf-coils (e.g. 6–8), which increases image reconstruction times. Finally, a significant amount of computation time is added to the image reconstruction process by the parallel image reconstruction. Since real-time reconstruction with minimum latency is a pre-requisite to safely guide the interventional instruments, an optimization of the reconstruction algorithm is necessary.

A trueFISP sequence was implemented on a clinical 1.5 Tesla MR system (Siemens Magnetom Symphony, Erlangen, Germany). The sequence included an active device tracking timing block (40 ms duration) in combination with automatic slice positioning. For the trueFISP acquisitions, the following parameters were used: FOV: 350×263 mm², matrix: 256×192, partial Fourier: 5/8, phase resolution: 80%, TR=4.3 ms, TE=1.9 ms, α=70°, SL=4 mm.

The sequence was tested in a pig model. An active 5F catheter with a solenoid rf coil at the tip was introduced into the pig's aorta and real-time MR images were acquired with and without parallel imaging. For parallel image encoding in all three spatial directions a posterior 6-element spine array coil and an anterior 2-element flexible body array coil were used, of which 4 selected elements were switched on during real-time parallel imaging. An acceleration factor of 2 was used with parallel MRI, and for each image acquisition 16 reference lines (8 auto-calibration lines) were acquired. With this intrinsic coil sensitivity sampling, sufficient information for the GRAPPA algorithm was available for image reconstruction.

Results and Discussion

With real-time parallel MRI the acquisition time per image could be decreased from 457 ms to 288 ms (i.e. 4 Hz). In Fig. 1 a comparison is shown between two images acquired with and without real-time parallel image reconstruction. In this anatomical region close to the level of the kidneys no major differences such as motion artifacts are visible, however, near the heart the increased temporal resolution of the parallel MR technique provides better delineation of the heart muscle and adjacent structures. Active tracking could successfully be combined with real-time parallel MRI. To optimize image reconstruction, the evaluation of the auto-calibration lines was only performed, when a movement of the slice was detected by active tracking.

Without active tracking, halvened resolution and 6 active coil elements, up to 10 images/s could be reconstructed and displayed with a latency of less than 0.5 s. The reduced number of coils available for reconstruction was not problematic, when coil elements were chosen carefully with respect to their location around the selected target structure. In the future, dynamic coil selection strategies will be employed to make efficient use of the image reconstruction processor.

References

[1] Bock M, et al. JMRI 19: 580-589 (2004)
[2] Griswold M, et al. MRM 47: 1202-10 (2002)