Real-Time Parallel Image Reconstruction for Interventional MRI

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Introduction

With the help of parallel acquisition techniques it is possible to reduce the MR measurement time by factors of typically 2 or 3. This acceleration is helpful for interventional MRI, if real-time image reconstruction techniques are available. The two fundamentally different reconstruction techniques for parallel MRI are SMASH [1] and SENSE [2]. With SENSE, reconstruction is performed in image space using previously acquired coil sensitivity maps. Therefore a SENSE reconstruction process can only be started after the complete raw data are sampled. The SMASH algorithm reconstructs missing k-space data using linear combinations of measured k-space lines so that interleaved data acquisition and k-space reconstruction are possible. The necessary reconstruction factors can be computed before the measurement or can be calculated during reconstruction using separately acquired k-space lines (GRAPPA [3]). We will further use the GRAPPA algorithm, which reconstructs the full k-space with separately acquired auto calibration lines.
In this work a trueFISP pulse sequence is presented, which combines parallel imaging with interactive slice orientation and automatic slice tracking. In studies with phantoms and volunteers we have evaluated the limits of the measurement parameters for real time reconstruction at fixed image resolution.

Material and Methods

The pulse sequence and reconstruction method was implemented on a clinical 1.5T MR scanner (Siemens Symphony, Erlangen, Germany). To take advantage of parallel imaging, we had utilized a 12 element thorax phased array coil for signal reception. For optimal encoding one half of the phased array coil was positioned anterior and the other posterior of a vessel phantom. The 12 element coils of the phased array were connected with the 8 ADC receiver channels of the MR scanner. Raw data processing was performed using the standard image reconstruction computer of the scanner (3GHz processor, 2 GByte RAM) with reconstruction code developed in the framework of the standard image reconstruction environment (ICE, Image Calculation Environment).
A time- optimised trueFISP pulse sequence was used in combination with automatic slice tracking and interactive slice orientation control. An active catheter with a small solenoid coil attached to the tip was inserted into the phantom and connected to a separate receive channel of the MR scanner [4]. Additionally, parallel imaging was implemented in the sequence. The GRAPPA algorithm was used with 16 reference lines and an acceleration factor 2. Additional acceleration was achieved by measuring only one half of k-space (Half Fourier, 50%) and reduced phase resolution (50%). The following parameters were used: FOV: 350 x 350 mm², matrix: 256x256, TR=3.65 ms, TE=1.82 ms, Flip Angle=70°, slice thickness=6mm. With these parameters an acquisition time of 210 ms per picture was achieved including tracking. In order to determine the number of coils at which image reconstruction could still follow data acquisition, the time between end of measurement and end of reconstruction was measured. To simulate the situation during an MRI-guided intervention, the measurement slice was positioned interactively in different directions. Slice positions were determined from the tracking data and automatically adjusted to the current catheter position.

Results and Discussion

Measurements with 6 coils and 1 catheter coil allowed a real time reconstruction rate of 5 frames/s with the above parameters. This image repetition rate was sufficient to smoothly navigate the catheter in the phantom. With these parameters the image reconstruction could follow a continuously changing orientation and position in real time. A matrix dimension of 128x128 allowed an image frequency of about 10Hz. As an example Figure 1 shows two images from the interactive tracking experiment together with corresponding planning image, which was used for the slice orientation. Artefacts were observed in the pictures by the parallel image acquisition. The anatomical interpretation however was not affected in this constellation. A higher number of reference lines reduced the artefacts. The real-time reconstruction demonstrated in this experiment has shown the potential of parallel acquisition techniques for real-time interventional MRI. With future advances in computer technology even higher reconstruction rates seem feasible.

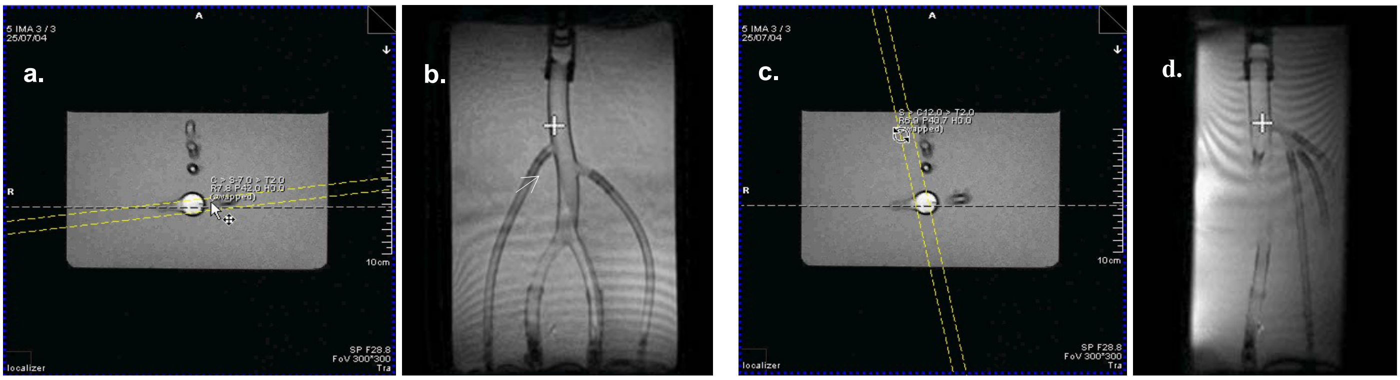

Fig. 1: Localizer images (a,c) with marked positions of the interactively positioned measurement slice. In the coronal trueFISP real-time image (b) the catheter tip is marked by a cross. Depending on slice position and slice orientation the real-time MR images show weak reconstruction artefacts (arrow) which are also present in conventional parallel MRI.

References

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