Cardiac Fluoroscopy Using Projection Reconstruction MRI

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Introduction

Recently several MR fluoroscopic scanners allowing near real-time data acquisition and reconstruction have been introduced [1-4]. Update rates of up to 10 images per second makes application of these scanners in the field of cardiac fluoroscopy feasible [3,5]. The use of spiral imaging techniques [3] shows very promising results but unfortunately dedicated reconstruction techniques to compensate for off-resonance effects are needed. The True FISP [5] approach suffers from artifacts resulting from the residual motion and flow within the heart.

We use a robust projection reconstruction (PR) technique for cardiac fluoroscopy which is known to generate only less severe artifacts due to motion or flow [6,7].

Methods

The acquisition scheme is based on a fast gradient echo steady-state sequence with data sampling along polar geometry through k-space [8]. Data acquisition was performed continuously over the cardiac cycle without any gating or triggering. For fast coverage of all spatial orientations of the object and further reduction of motion related artifacts several interleaved angularly under-sampled data sets were acquired which combined yield the desired resolution [8]. For improvement of the temporal resolution two or four gradient echoes were acquired after each excitation as proposed recently [9,10]. Reconstruction and viewing of the data was performed using a dedicated back-projection hardware [2] performing a sliding window reconstruction [1] at video rate with 25 frames per second.

Results

All experiments were conducted on a Philips Gyroscan ACS-NT scanner operating at 1.5T. It is equipped with a PowerTrak 6000 gradient system providing a maximal gradient amplitude of 23mT/m within 200us. For real-time reconstruction the scanner is equipped with a modified backend [2]. During reconstruction no off-resonance correction was applied. All images shown were acquired using two independent circular receive coils with diameter of 20cm (Philips Cl). All images shown are temporal snapshots extracted from a time series during continuous scanning with parameters as in Table 1.

<table>
<thead>
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<th>proj</th>
<th>echoes</th>
<th>TE [ms]</th>
<th>TI [ms]</th>
<th>TR [ms]</th>
<th>Tacc [ms]</th>
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<tr>
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<td>1</td>
<td>1.1</td>
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<tr>
<td>2c,d</td>
<td>96</td>
<td>2</td>
<td>1.1</td>
<td>3.3</td>
<td>160</td>
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</table>

Table 1. Acquisition parameters for examples in Fig.1,2. During the acquisition of all data sets a four interleaves were used and a 128² matrix was reconstructed, the in-plane resolution was 2.9x2.9mm².

Figure 1 shows an axial, a coronal, and a sagittal view through the human heart obtained without any gating or triggering (see Tab. 1 for detailed acq. parameters). Although the acquisition time for an entire data-set was approx. 170ms, all images show a clear visualization of the heart without severe motion or flow-related artifacts.

Figure 2 shows a comparison of a single-echo acquisition (a,b) and a double-echo acquisition (c,d). Direct comparison of the corresponding single-echo and double-echo images clearly demonstrates the reduced temporal blur in case of the double-echo acquisition.

Due to the unique traversal through k-space we limited the maximal number of echoes used to four in order to avoid streaking artifacts caused by the T2* decay.

Even in case of a single-echo acquisition the image quality is sufficient for real-time navigation. The use of two or four echoes in combination with slight angular under-sampling allowed image acquisition update-rates up to 10 new data-sets per second clearly showing the dynamics within the heart.

Discussion

We have shown that the projection reconstruction technique is well suited for cardiac fluoroscopy. Its robustness to flow and motion as well as its robustness regarding off-resonance effects makes it to a promising alternative to spiral and especially to spin-warp-based acquisition techniques.

References