Motion-Corrected Intravascular MRI with an Active Tracking Catheter

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Introduction

Intra-arterial MRI has recently been demonstrated in several arterial blood vessels using catheter coils with an opposed solenoid coil configuration [1]. In larger arteries such as the aorta high-resolution imaging can be difficult, because flow-related motion of the catheter significantly disturbs the imaging process. With the help of ECG triggering, artifacts can be reduced if the motion of the catheter in the blood stream is periodic, however, this is not always the case if more complex flow patterns are present. The present study proposes a method of acquiring intra-arterial images using additional MR tracking information. In this approach, the position of the catheter tip is continuously extracted from projection data to use them for retrospective gating of the acquired images.

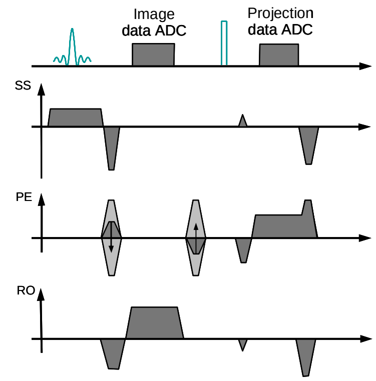

Fig 1 Schematic of the 2D FLASH projection pulse sequence with projection in phase encoding direction. The projection direction can be chosen before the start of the measurement.

Materials and Methods

The intravascular projection and imaging technique was implemented on a clinical 1.5 Tesla whole body MR system (Siemens Magnetom Symphony, Erlangen, Germany). For data reception an intravascular 5F tracking catheter (Interventional Imaging, Inc., Cleveland, OH, USA) that is equipped with two opposed solenoid RF-coils was used. Close to the tip, the catheter has a guidewire lumen of 0.018 in, and a 0.016 in gold coil guidewire (Radifocus®, Terumo, Tokyo, Japan) was used for catheter positioning.

An imaging and tracking pulse sequence was implemented as a combination of a 2D FLASH sequence with the acquisition of projection data (Fig 1). After the acquisition of each k-space line, a non-selective excitation followed by the acquisition of a single projection data set is applied to determine the position of the imaging coil in this direction. To suppress background signal from static tissue, additional dephaser gradients are applied orthogonal to the readout direction of the projection.

The sequence was tested on a healthy anesthetized pig (body weight: 80 kg). The tracking catheter was placed in the animal's right renal artery (Fig 2) and in the aorta close to the origin of the renal arteries. After the positioning of the catheter, 30 data sets were acquired using the following imaging parameters: TR = 9.1 ms, TE = 4.8 ms, FOV = 150×150 mm², matrix = 256×256, slice thickness = 3 mm, α = 15°. Projection parameters: TR = 7.4 ms, TE = 3.5 ms, FOV = 500×500 mm², matrix = 256×256, α = 5°. The measurements were repeated for all three spatial directions of the projection data.

The projection data were analyzed using an autocorrelation algorithm to determine the catheter position with sub-pixel precision. For motion compensation, a range of positions was defined which were accepted as input for the subsequent image calculation. After determining the most frequent catheter tip position for each of the six data sets, the acceptance intervals were defined individually in the range of 0.03 mm to 1.2 mm, with steps of 0.03 mm, and in total 40 images were reconstructed.

Fig 2 Catheter in renal artery

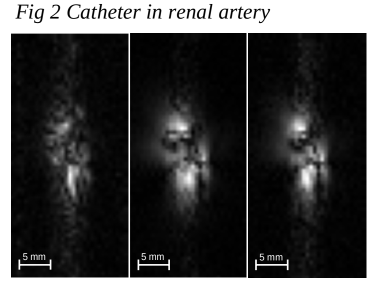

Fig 3(a) uncorrected image, renal artery, y direction (b) mean image, appears broader because of blurring due to catheter motion (c) motion corrected image

Results and Discussion

Catheter shifts of $\Delta x/\Delta y/\Delta z$ = 1mm / 0.2 mm / 0.1 mm were detected in the aorta and of 0.8 mm / 0.6 mm / 0.4 mm in the renal artery, respectively. Figure 3 shows a comparison between a single uncorrected image, the average over all 30 data sets, and a motion-corrected image in the renal artery.

As expected, the images with the smallest acceptance window (0.03 mm) had a very low SNR whereas a broader acceptance range increased the SNR because multiple measured k-space lines were averaged. When the acceptance interval was of the same magnitude as the catheter shift amplitude, significant blurring artifacts became visible, which became most pronounced, when all available image data were used (Figure 3b). The best image quality was achieved at an acceptance range of about one third of the shift amplitude, i.e. $\Delta x/\Delta y/\Delta z$ = 0.3 mm / 0.09 mm / 0.06 mm in the aorta and 0.24 mm / 0.18 mm / 0.12 mm in the renal artery (Figure 3c). The use of projection data for motion correction leads to an improvement in image quality compared to uncorrected images. The increase in acquisition time might be reduced in future modifications of the sequence, if e.g. the projection data are not sampled for every k-space line.

References

[1] Hillenbrand CM et al. MRM 2006; 23:135-144