Automatic Slice Positioning of the Interventional Guidewire Using Passive Paramagnetic Markers

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Objective: In interventional MRI localization and visualization methods of interventional devices can be broadly classified into active and passive tracking. In active tracking, locally sensitive receive coils enable a real time tracking of the interventional device [1]. In passive tracking, paramagnetic markers induce a susceptibility based image contrast which is used to track the position of the device [2]. Susceptibility based methods are slower as compared to active tracking, but is considered to be a safer approach than active tracking suffering from RF heating [3]. In this work, a novel method for passive real-time tracking of paramagnetic markers is proposed, termed Projection Reconstruction Imaging using echo-Dephasing (PRIDE). It is based on the acquisition of projections along all three physical (X, Y, and Z) axes, enabling a real-time positional update of the slice to the detected device location.

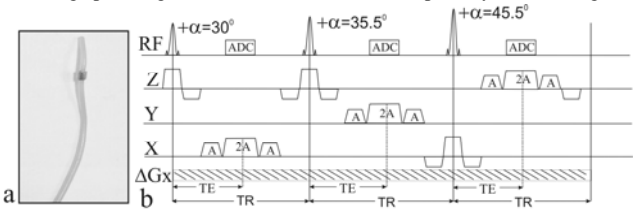

Figure 1 *a) Interventional guidewire with the paramagnetic marker wrapped around it b) PRIDE sequence with readout along X,Y and Z and increasing flip angles during each repetition.*

Materials and Methods: Paramagnetic materials wrapped around a guidewire (Fig. 1a) induce local gradient fields (ΔGx in Fig 1b) in surrounding tissues. Using PRIDE (Fig. 1b), dephasing gradients exploit marker-related gradient fields (ΔGx) along all three physical axes to acquire three orthogonal projection images. The local gradients may compensate for the dephasing in the readout to form a normal echo during each projection whereas background signals are heavily suppressed as a result of the echo-dephasing nature of the sequence. The flip angle was adjusted for every projection to compensate for the intrinsic signal loss from dephasing in order to achieve similar signal strengths for all locally rephased signals.

A custom-built phantom with 11 mm diameter tubes to model the blood flow in large vessels and to insert the guide wire was used. The tubes were immersed in gadolinium-doped water and were surrounded by a 2% agarose gel doped with 0.5 mM (v/v) copper sulphate concentration to closely resemble the relaxation times of fat tissues. In vivo images were obtained from a fully anesthetized domestic pig and experiments were conducted in accordance with the regulations of the institution (in collaboration with University Hospital, Essen). All the measurements were done on a Siemens Espree 1.5T scanner.

The automatic slice positioning using PRIDE was interleaved with bSSFP (balanced Steady State Free Precession). Upon reception of the projection data from PRIDE sequence, calculation of 1D FT followed by maxima detection, conversion of three maxima into magnetic co-ordinates and real-time feedback of the marker position was done within the software framework provided by the manufacturer. The PRIDE parameters were: FOV (readout) 20 cm; Base resolution 256; Slice thickness 20 cm; TE/TR 3/6 ms; Flip angles=30^0(X), 35.5^0(Y), 45.5^0(Z) (for in vivo; 50^0); Bandwidth/pixel=450 Hz.

Results: Fig 2 depicts in-vivo coronal bSSFP image with typical image artifact due to paramagnetic material and corresponding PRIDE projections along X and Z directions. Peaks corresponding to the marker position are clearly discernible (red circled) for every projection with good suppression of the background signals yielding minimum PNR ratios of about 2.5. Automatic slice positioning is demonstrated for coronal planes in Fig 3. Localizer images in sagittal and transversal planes indicate slice positions before (Fig 3a, Fig 3b) and after (Fig 3d, Fig 3e) real-time feedback with corresponding coronal images acquired before (Fig 3c) and after real-time feedback (Fig 3f). Slice positioning is slightly shifted from the marker's center-of-mass by few millimeters, since local gradient compensation takes place outside of the marker position. Slice positions are indicated by red circles. The total time for post-processing calculations and feedback was about 2-3 ms.

Conclusion: Our initial in-vitro and in-vivo results demonstrate that PRIDE based passive detection of paramagnetic marker can successfully be used for real-time slice positioning. As a result, PRIDE yields active tracking-like performance while completely avoiding heating safety hazards.

Reference: [1] Dumoulin et al., MRM 29(3): 1993. [2] Bieri et al., MRM 58:1242-1248, 2007. [3] Ladd et al., MRM 43:615-619, 2000.

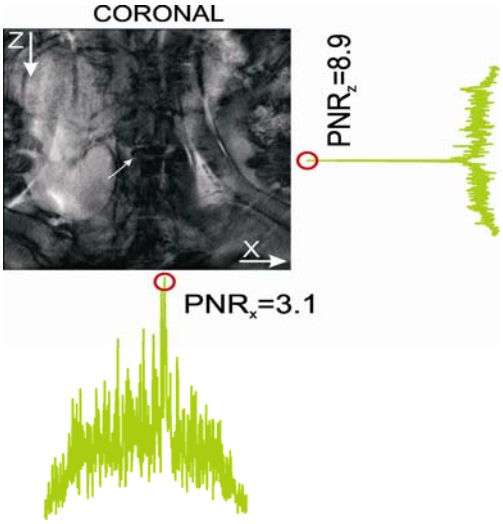

Figure 2 *In vivo projections along X and Z directions with coronal localizer image. Red circles indicate maxima corresponding to marker position.*

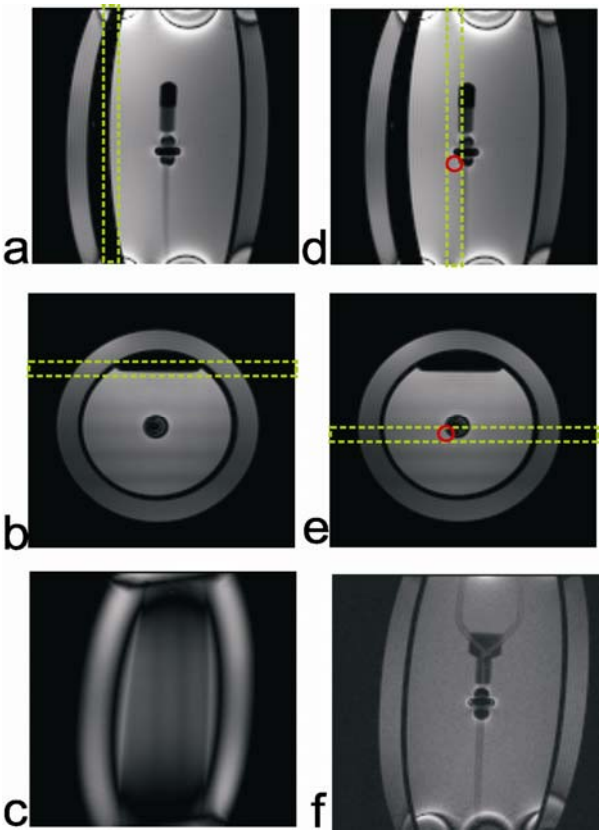

Figure 3 *Real-time Feedback for Automatic slice positioning: Localizer images in sagittal and transversal planes showing slice positions before (a), (b) with corresponding coronal image (c) and after (d), (e) with corresponding coronal image (f). Red circles indicate detected slice position using PRIDE sequence.*