Variable Echotimes in Radial Acquisitions to Achieve a Uniform Artifact for Passive MR Guidewires

Axel Joachim Krafft[1,2], Simon Reiß[1], Klaus Duering[3], and Michael Bock[1]
[1]Radiology - Medical Physics, University Medical Center Freiburg, Freiburg, Germany, [2]German Cancer Consortium (DKTK), Heidelberg, Germany, [3]MaRVis Medical GmbH, Hannover, Germany

Introduction

Guidewires are fundamental tools in catheter-based interventions. Unfortunately, the commercial metallic guidewires used in X-ray guided procedures cannot be employed in MR-guided interventions due to potentially hazardous radio-frequency-induced heating [1]. To avoid heating, passive paramagnetic markers are typically integrated into the device which generates a local artifact leading to a negative contrast in the vicinity of the markers. However, in gradient echo imaging these artifacts depend on various imaging parameters, in particular on the echo time (TE) and on the orientation of the marker relative to the main magnetic field (B_0) [2].

Recently, MR-compatible guidewires with embedded iron particles were introduced [3] which exhibit a wide artifact for orientations perpendicular to B_0 and a much narrower artifact parallel to B_0 (Fig. 1). Here, we present a radial acquisition scheme to realize a uniform, orientation-independent artifact for improved guidewire visualization.

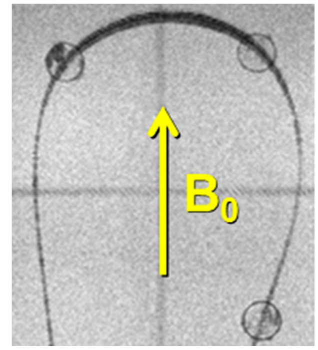

Fig. 1: Cartesian coronal GRE image of passive guidewire.

Materials & Methods

In contrast to conventional Cartesian k-space sampling, radial acquisition schemes [4] sample the k-space data in projections so that each radial line contains information about the k-space center, and thus, contributes equally to the generated image contrast. K-space is filled by rotating the readout (RO) direction, and each RO line collects a slightly different angular projection. Our sequence concept exploits this concept to achieve different weightings of the guidewire artifact by changing TE with the RO direction, as the artifact size increases with TE.

A 2D radial GRE sequence was implemented on a 1.5 T whole body MR system (Siemens Symphony) that employs different TEs for each spoke depending on the orientation of the RO direction with B_0 (Fig. 2). For the projection that uses an orientation of the RO gradient parallel to B_0, the radial spoke (red line in Fig. 2) is acquired with the shortest TE (TE_{min}), and the longest TE (TE_{max}) is realized when the RO direction is perpendicular to B_0. For the other directions, sine-modulated TEs depending on the angular orientation θ (angular increments: φ) of the RO gradient are used: $TE(\theta) = TE_{min} + (TE_{max}\text{-}TE_{min})\cdot\sin(\theta)$. Two versions of the variable-TE sequence were implemented: (i) fixed repetition time (TR), i.e. each spoke uses the same TR_{fix}, and (ii) variable TR, i.e. each spoke is acquired with the shortest possible $TR_{var}(\theta)$ depending on the current TE(θ).

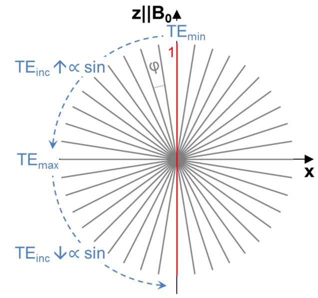

Fig. 2: Radial acquisition with sine-modulated TEs depending on direction of RO gradient.

For proof-of-concept measurements, a prototype passive MR guidewire (MaRVis Medical GmbH, Germany) with embedded small iron particles was placed in a water-filled container so that sections of the guidewire were aligned parallel and perpendicular to B_0 (Fig. 1). The variable-TE sequences were applied with the following parameters: TE_{min} = 1.8 ms, TE_{max} = 10.8 ms, TR_{fix} = 14 ms, TR_{var} (θ) = 3.8-14 ms, FOV = 280×280 mm^2, reconstructed matrix: 128×128, α = 10°. For comparison, images were also acquired at fixed TE_{min} and TE_{max}. To investigate if the observed artifact simply arises from an averaging effect of short and long TEs, the sequence was additionally compared to radial acquisitions that alternate between TE_{min} and TE_{max} between neighboring spokes (case (i)/(ii): data sampled with TE_{min}/TE_{max} for RO in z-direction).

Results & Discussion

Figure 3 compares the artifacts of the passive guidewire for all radial pulse sequences. As expected, the artifact size depends on TE: For radial acquisitions with fixed TE, the smallest artifact size of 4.9/1.8 mm (perpendicular/parallel to B_0) is seen for TE_{min} (Fig 3a), and the largest size of 9.7/3.1 mm for TE_{max} (Fig. 3b). With alternating TEs more balanced artifact dimensions of 6.1/3.7 mm (case (i), Fig. 3c), and 6.0/3.8 mm (case (ii), Fig. 3d) are found. However, the negative contrast for orientations parallel to B_0 is substantially diminished (orange arrows) reducing the overall visibility. For the new variable-TE sequences artifact dimensions of 7.2/4.9 mm (fixed TR, Fig. 3e) and 6.7/4.5 mm (variable TR, Fig. 3g) were found with a well-defined negative contrast for both orientations (green arrows). However, when the TE modulation is inverted, i.e. TE_{max}/TE_{min} for RO orientation parallel/perpendicular to B_0, a wide artifact perpendicular to B_0 (10.2 mm for fixed TR, 10.5 mm for variable TR) and a narrow artifact parallel to B_0 (3.6 mm and 3.5 mm) is seen (Figs. 3f and 3h).

Our preliminary data indicates that a TE-modulated radial acquisition scheme can provide a more uniform guidewire artifact. Through the use of relatively long TE to increase the artifact size perpendicular to B_0, the sequence is slower (here about 2.3-fold) than a sequence with the shortest possible TE and TR for all spokes. The sequence can be accelerated (here by a factor of about 1.6) without degrading the intended artifacts using variable TRs. In general, radial acquisitions are intrinsically insensitive to motion which might be advantageous in MR-guided interventions. However, further analysis is required to identify optimal TE values to balance uniform guidewire visualization with short acquisition times. Future work could aim at combining the TE-modulated radial sampling with the white marker phenomenon [5] to provide a uniform positive guidewire contrast.

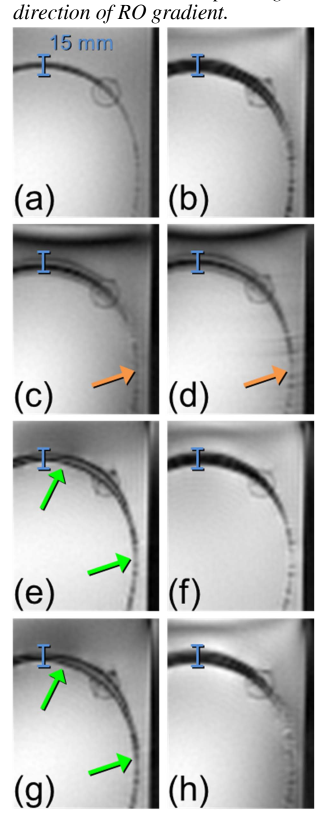

Fig. 3: Comparison of guidewire artifacts for different radial GRE acquisitions. See text for details.

References

[1] Nitz et al. JMRI 2001;13:105-14.
[2] Rubin et al. Invest Radiol 1990;25:1325-32.
[3] Mekle et al. JMRI 2006;23:145-55.
[4] Lauterbur, Nature 1973;242:190-1.
[5] Seppenwoolde al. MRM 2003;50:784-90