Fast T1-Weighted Spin-Echo Imaging with Fat Water Separation Using A Spiral Readout

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Introduction T1-weighted Spin Echo (SE) imaging is widely used in the clinic, in particular for post-Gd studies of various brain diseases. Conventional SE imaging based on a Cartesian trajectory is sensitive to motion and flow artifacts. Several alternatives have been proposed based on PROPELLER acquisition[1,2]. T1FLAIR PROPELLER[1] uses conventional TSE, but its contrast is FLAIR-based. SE PROPELLER[2] utilizes SE and groups data from different TRs to form composite blades so inter-shot motion is a concern. For certain applications (e.g., skull-based tumors) fat signal is helpful in interpreting the pre-Gd images but undesirable in the post-Gd images. Water/fat separation with current SE sequence results in long scan time since parallel imaging is still challenging for Cartesian SE imaging. In this work we propose a SE technique employing a spiral readout with multiple TE shifts to generate T1-weighted images insensitive to motion/flow artifacts. This technique also provides simultaneous water/fat separation and flexibility in scan time reduction.

Methods In the proposed spiral SE technique, the conventional Cartesian readout is replaced by a spiral readout to allow for faster data collection. The spiral trajectory also provides insensitivity to motion due to oversampling near the center of k-space, as well as insensitivity to in-plane flow due to the zero gradient moments at the center of k-space. Interference from FID or through-plane flow is minimized by increasing the crushing gradient[3].

To allow for water/fat separation, data are acquired at multiple TE shifts without fat suppression (which is required for regular spiral imaging). Another benefit of this multi-TE acquisition is the field map (from water and fat separation), which can be used for deblurring the images. This eliminates the need of a separate scan for the field map.

The sequence was implemented on a Philips Ingenia 3T scanner. Volunteer data were acquired with the following protocol: FOV = 230x230 mm^2, resolution = 1x1 mm^2, slice thickness = 5 mm, slice gap = 1 mm, 21 slices, 35 spiral arms, TE = 10 ms (with 3 shifts of 0, 0.7, and 1.4 ms, respectively), TR = 450 ms, NEX = 2, scan time = 3:12. Cartesian SE data sets were also obtained as a reference with flow compensation using a similar protocol with FOV = 230x190 mm^2, TR = 500 ms, NEX = 1, sand can time = 3:14. A saturation band below the imaging volume was turned ON and OFF in Cartesian SE to illustrate the flow artifacts. Neither flow compensation nor a saturation band were used in the spiral SE scan.

The data were processed using GPI[4]. Three images at different TE shifts were first reconstructed. Then the Dixon method[5] was used to generate the water and the fat images, as well as a B0 field map. The B0 field map was used to deblur the water and fat images.

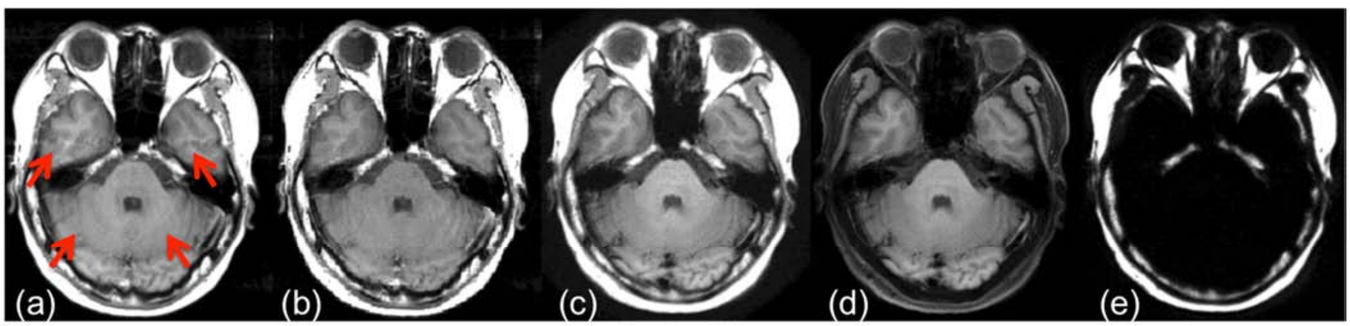

Fig. 1 Images acquired using Cartesian SE with flow compensation, without (a) and with (b) a saturation band. c) is the spiral SE image combined from the separated d) water and e) fat images.

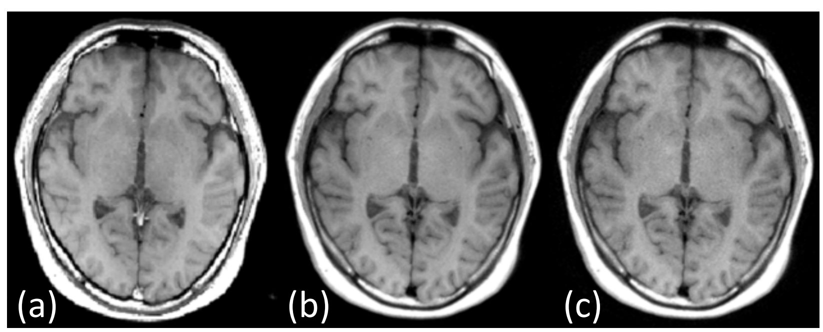

Fig. 2 a) Cartesian and b) spiral image with acquisition time = ~3:12. c) is the spiral image with acquisition time = 1:36.

Results and Discussion Fig. 1 shows the axial image across the temporal lobe and cerebellum. The image acquired using Cartesian SE without a saturation band (Fig. 1a) shows significant flow artifacts (even with flow compensation), as pointed to by the red arrows. The use of a saturation band (in addition to flow compensation) significantly reduces the flow artifacts, but residual artifacts may be still noticeable (Fig. 1b). Fig 1c-1e are the combined water/fat, water-only, and fat-only images acquired using the spiral SE technique. These spiral images show comparable SNR/contrast to the Cartesian results but with no visible artifact.

Fig. 2 demonstrates the reduction in scan time with the spiral SE technique. With the same scan time (~3:12), the Cartesian image (Fig. 2a) and the spiral image (Fig. 2b) show comparable SNR/contrast. Since the spiral data (Fig. 2b) are acquired with NEX = 2, half of the data can be used to reconstruct the images with comparable quality except the tradeoff in SNR (Fig 2c). This is equivalent to a 1:36 scan (a 2x reduction in scan time). The scan time can also be manipulated by adjusting the number of spiral arms.

Conclusion A SE technique is developed with a spiral readout and multiple TE shifts, allowing for T1-weighted imaging with minimal flow/motion artifacts, the capability of simultaneous water/fat separation, as well as the flexibility in scan time control.

References 1. Li Z, et al. ISMRM. 2008;16:1399. 2. Skare S, et al. ISMRM, 2012;20:4173. 3. Wang WT, et al. ISMRM 2006;14:2184. 4. Zwart NR, et al. Graphic Programming Interface. ISMRM Data Sampling and Reconstruction Workshop, 2013. 5. Berglund J, et al. MRM 2010;63:1659.
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