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 acquisition1,2. T1FLAIR PROPELLER1 uses conventional TSE, but its contrast is FLAIR-based. SE PROPELLER2 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 gradient1.

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 mm², resolution = 1x1 mm², 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 mm², TR = 500 ms, NEX = 1, and scan 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 GPI4. Three images at different TE shifts were first reconstructed. Then the Dixon method5 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.

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.


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