Radial Single-Shot STEAM MRI

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Rapid MR imaging using the STEAM technique yields single-shot images without any distortion artifacts (1). Because all echoes are RF refocused, it arises as a promising alternative to EPI in situations where high anatomical accuracy is needed, e.g. for DTI. However, due to the limited magnetization available, the spatial resolution is restricted when using conventional Fourier encoding.

To overcome the problem, this study combined single-shot STEAM with a radial encoding scheme (2). Hence, the undersampling properties of the radial trajectory can be exploited to obtain in-plane resolutions otherwise not achievable in a single-shot scenario.

References
2. Block KT and Frahm J, submitted
4. Block KT, Uecker M and Frahm J, MRM, in press

Methods

Figure 1 shows a schematic diagram of the sequence. It starts with a preparation of the magnetization employing two slice-selective 90° pulses, followed by an acquisition part which is repeated for every spoke measured. Interleaved ordering of the spokes over 360° and variable flip angles (3) were used to distribute the signal intensity more equally in k-space. All experiments were conducted at 2.9T with a 12-channel head coil covering a 208 mm FOV. An isotropic compensation mechanism was employed to avoid gradient timing errors.

The images were reconstructed offline using an iterative method which incorporates prior knowledge to compensate for incomplete radial acquisitions (4). Further, the approach suppresses noise efficiently by constraining the total variation (TV) of the object.

Discussion

Figure 2 compares the best resolution obtainable with Cartesian single-shot STEAM MRI (5) to the radial version for phantom and human brain data. Whereas the Cartesian images are limited to a 2.0 mm in-plane resolution, the radial images present with 1.0 mm resolution. This fourfold reduction in voxel size is best appreciated in the phantom images, but also visible for the human brain when focusing on tissue borders or the skull. For comparison, the right side shows spin-echo EPI images revealing typical distortion artifacts.

Figure 3 shows radial images of the human brain with in-plane resolutions ranging from 2.0 mm to 1.0 mm. Higher resolution requires an increased bandwidth to maintain the sequence timing and, therefore, leads to increased noise. However, because noise in the reconstructed image is largely suppressed by the application of a TV constraint, the effect translates into a slight loss of resolution rather than reduced SNR.

Figure 4 shows radial images of the human brain reconstructed from 32, 48 and 64 spokes. All images recover the object with reasonable quality, although the reconstruction from 32 spokes suffers from minor residual undersampling artifacts. In general, the images demonstrate that radial sampling offers considerable freedom for trajectory design, allowing to tailor imaging protocols for specific needs.

Conclusion

This work presents a new method for high-speed MRI based on the use of radial encoding for single-shot STEAM. The combination adds complementary advantages: while RF refocused echoes allow for the utilization of radial k-space sampling, the undersampling capability of radial encoding makes optimal use of the limited magnetization available. Because the base resolution can be selected independently from the number of stimulated echoes, the method offers a much higher in-plane resolution than comparable Fourier encoded versions.

References
2. Block KT and Frahm J, submitted
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