

**Reversed Spiral Imaging for increased $T_2^*$ Contrast**

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**Introduction:** Spiral imaging is known to achieve very short effective echo times if the k-space trajectories are traversed starting at the origin of k-space and ending at a boundary [1]. Thus, this type of traversing k-space can be called forward spiral approach. However, there are a lot of applications, in which longer effective echo times are desirable to introduce $T_2^*$ contrast as e.g. in functional MRI [2]. To achieve this, the data acquisition block of the forward spiral can be shifted in time resulting in an increased repetition time (TR) of the sequence. However, to this end, a reversed spiral trajectory may be used, in which k-space is scanned from the boundary towards the center (c.f. Fig.1). Thus, the low spatial frequencies are sampled at long effective echo times without the need to increase TR. This might be a special advantage when short repetition times are of prime importance in $T_2^*$ contrast enhanced applications, as for instance, in real-time applications.

In this work, the reversed-spiral approach is studied with respect to its contrast and flow properties. Results obtained by phantom and in-vivo experiments are shown and discussed.

![Fig.1. Schematic representation of different approaches to introduce $T_2^*$ contrast in spiral imaging: (a) time shifted forward spiral imaging, (b) reversed spiral imaging. The block at the beginning denotes the RF excitation.](image)

**Methods:** Experiments were performed on a 1.5 T whole body scanner (Gyroscan, ACS-NT, Philips Medical Systems). Images were acquired using interleaved spiral trajectories with variable angular speed. For the forward and the reversed approaches the same reconstruction was employed, with the only difference that the reversed spiral data were mirrored in the time domain prior to reconstruction. Real-time imaging experiments were performed using an ultra-fast reconstruction unit [3]. Correction for spatially varying $B_0$ inhomogeneity was performed by conjugate phase reconstruction [4] based on a measured field map. The contrast behaviour and the flow sensitivity were analysed in theoretical simulations and experiments.

**Results:** It was expected that the reversed-spiral approach is more sensitive to static magnetic field inhomogeneity and to gradient-system imperfections. Artefacts result if the actual k-space trajectory does not end precisely at the k-space origin. This effect was negligible, however, in the system used, and did not noticeably degrade the image quality.

Image degradation (mainly blurring) caused by spatially varying $B_0$ inhomogeneity could be reduced with the same effectiveness using the conjugate phase reconstruction just as for the forward spiral scheme.

Compared with the forward approach, the reversed spiral is more sensitive to motion and flow effects unless special precautions are taken. This sensitivity can be reduced by employing the first gradient moment nulling techniques [5-6]. The first gradient moment of the reversed approach can then be made to vanish in the centre of k-space, as is the case for the forward spiral. This reduces the flow sensitivity of the reversed spiral considerably. However, a small flow artefact still remains. This consists in a displacement of pixels exposed to in-plane flow, which shifts these pixels slightly into the flow direction. This effect can simply be understood as a time-of-flight effect due to the late acquisition of the central portion of k-space data in the reversed spiral case.

$T_2^*$ contrast, observed in-vivo, is slightly different for forward and reversed spirals. Especially, fast $T_2^*$ relaxing or flowing species appear differently in the two approaches. In forward spiral imaging their signals almost disappear due to blurring whereas in the reversed approach signal contributions are visible due to the early acquisition of the high spatial frequencies.

![Fig.2. Comparison. Top row: High resolution $T_2^*$ weighted brain images (TE,ff.:40ms, matrix:512, AQ window:30ms, interleaves: 40, slice:8mm, fat suppr.) (a) forward shifted spiral (b) revered spiral. Below: extracted real-time frames (matrix:256, AQ window:12 ms, interleaves:20, slice:8mm, fat suppr., 4 element coil). (c) forward spiral (TE,ff.:5ms), (d) revered spiral (TE,ff.: 20ms).](image)

**Discussion:** Imaging with reversed spiral k-space trajectories provides strong $T_2^*$ contrast. The method must be combined with first gradient moment nulling to reduce flow and motion sensitivity. Forward and reversed spiral sampling can be used to sample either the FID or the echo signal in steady state sequences. A promising field of application for the reversed spiral is functional brain imaging or real-time MR imaging, where a short repetition time is essential.

**References**