# High resolution 3D-myelography and –ventriculography using inner volume RARE with optimized k-space trajetories

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## Introduction

The possibility to use single shot RARE-experiments with long echotrains to generate images from fluid filled spaces like the ventricles or the spinal canal has been suggested already in 1986 (1). 3D-implementations produced highly detailed datasets of complex structures of the CSF-filled spaces with the advantage, that segmentation for 3D-surface rendering is exceptionally easy due to the unique contrast behaviour of the experiment, which totally avoids overlap from soft tissue structures (2). Early implementations of the technique were reasonably time consuming with acquisition times in the order of several minutes. More recently single shot 3D-implementations using fast gradient systems could be demonstrated (3). The purpose of this study is the development of a flexible approach for routine applications based on high resolution 3D-imaging after volume selection of a target volume.

## Methods

All experiments were performed on a 1.5T system (Siemens Magnetom Symphony) equipped with ultragradients (20 mT/m, 40 T/m/s risetime). The basic pulse sequence used a CPMG-echo train with an echo spacing of 9.4 ms. Inner volume selection was achieved by using a different slice selection for the excitation pulse compared to the ensuing 180 refocusing pulses. The slice thickness and orientation for both slices can be chosen arbitrarily using the graphical interface of the scanner, even non-orthogonal slices can be realized. The size of the 3D-dataset can be chosen independently from the slice parameters of the selection pulses in order to allow for comfortable placement of the volume of interest in the final dataset.

Signal was read out line-by-line under a conventional constant read-out gradient. For the 2D- and 3D-phase encoding gradient different trajectories were implemented:

- linear consecutive as in conventional 3D-scans.
- Square spirals around a pivot point, which is not necessarily at the center of k-space.
- Sorted in ascending order by the euclidian distance to the chosen center point of k-space as suggested by Wilman for contrast enhanced MRA(4).

Experiments could be performed either in single shot mode or as segmented scans with an arbitrary number of excitations. In the latter case, the chosen k-space trajectory was scanned in an interleaved manner.

## Results

Comparing the point spread functions (PSF) of the different approaches it is obvious, that a linear line-by-line trajectory leads to a considerable anisotropy of the T2-dependend signal broadening. The square spiral and the sorted trajectories show a much more isotropic PSF. Fig.1 demonstrates the rectangular symmetry of the PSF for the square spiral compared to the radial symmetry of the sorted trajectory.

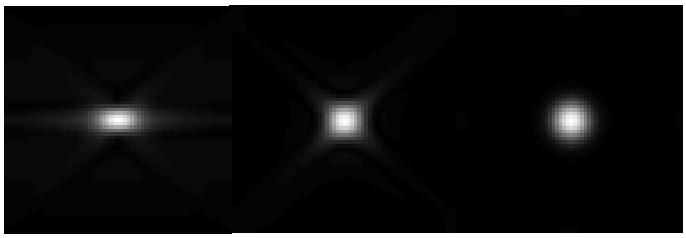

Fig.1 Two-dimensional point-spread functions for a linear (left), square spiral (middle) and optimized (right) sampling of the 2D/3D k-space data. The PSFs were generated by convolution of the image of a point with an exponential decay curve (T2=1/8$^{th}$ of the length of the echo train).

Fig.2 shows sections of a dataset of a normal volunteer in the region of the Foramen Monroe. The acquisition matrix was 64 x 64x 256 with 1mm isotropic resolution. Data were acquired as segmented scan with 16 acquisitions and a repetition time of 5s (total acquisition time 1:20 min.). Small structures like vessels, nerves and the aquaeduct are demonstrated in exquisite detail.

## Discussion

The images acquired so far demonstrate the feasibility of performing inner volume 3D-imaging with extremely high resolution within very reasonable acquisition times. The nonlinear k-space trajectories overcome the inherent disadvantage of conventional approaches, in which the number of partitions had to be fitted to the number of excitations in order to avoid discontinuities in the T2-dependent signal attenuation leading to artifacts.
Although the current study was focussed on myelographic implementations with very strong T2-contrast, the flexibility of the implementation also allows to generate 3D-datasets with lesser T2-weighting.

## References

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Fig.2 examples from a 3D-acquisition of a 64x64x256 mm$^3$ volume around the brain stem.