Accelerating TOF MRA in Clinical Practice using Sparse MRI with Variable Poisson Density Sampling

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Introduction: The recently described technique *"Time-Of-Flight with sparse undersampling" (TOFu)* (1,2) has demonstrated the potential to accelerate TOF MRA, using a variable density spiral phyllotaxis trajectory, which provides a fast and efficient Cartesian sampling pattern for sparse MRI techniques (3). Nonetheless, in particular for thin slabs acquisitions, the Spiral phyllotaxis technique can induce coherent patterns which may limit the acceleration performance and induce image artifacts. According to the sparse MRI theory, improved incoherence should allow better performance with iterative reconstruction techniques. In this work, a sparse TOF technique using a variable Poisson density sampling pattern with improved incoherence was implemented on a standard clinical scanner and evaluated in volunteers and patients.

Materials and Methods: Data were acquired in 10 healthy volunteers and 3 patients with neurovascular diseases on a 3T MR system (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) and using a 20-channel head/neck RF coil for signal reception. The sparse TOF prototype used sampling patterns based either on the Spiral phyllotaxis approach or a variable density Poisson distribution (4,5) (Fig.1). The reconstruction of the sparse MRA data was performed using a non-linear iterative SENSE-based algorithm (6) with a constraint enforcing sparsity. The sparsifying transform used Haar wavelets, and sparsity was enforced by the L1-norm of the wavelet coefficients (7). The iterative reconstruction was implemented on the standard reconstruction system to provide inline reconstruction of the images in approx. 6 minutes. The TOF images from both sparse sampling patterns were compared against conventional TOF with parallel imaging (GRAPPA TOF) in the PE direction (3-fold acceleration) (Fig.1). The other parameters for TOF imaging were kept identical between GRAPPA TOF and sparse TOF: TE 3.43 ms, TR 21 ms, 18 degrees flip angle with TONE ramp, 3D centric-out reordering, travelling venous saturation, bandwidth 188 Hz/pixel, integrated reference lines, field-of-view 220 x 200 x 69 mm^3, 2-fold interpolation in all directions.

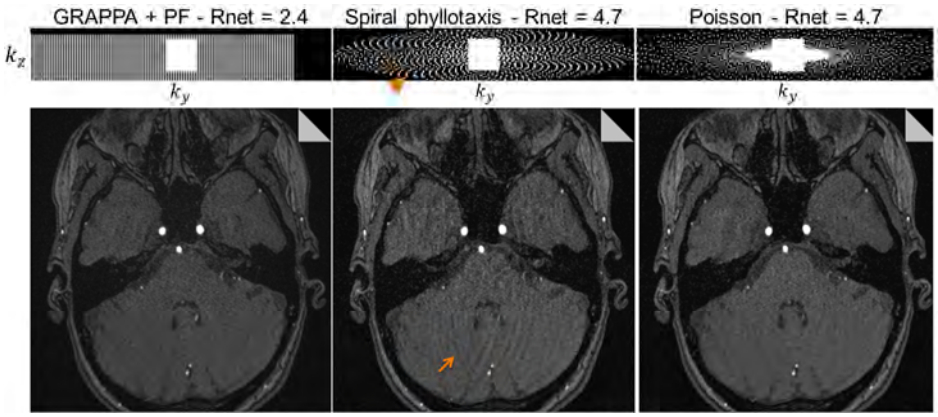

Fig.1: Sampling patterns and source images in one representative volunteer for parallel imaging, Spiral phyllotaxis and variable density Poisson. The arrowhead and arrow point toward coherent patterns and the resulting image artifacts, respectively.

Results: In the thin slabs used for TOF MRA, the Spiral phyllotaxis sampling pattern produced locally coherent patterns that generated discrete artifacts on the reconstructed source images (Fig.1). For this reasons, the sampling pattern with variable density Poisson has been used on subsequent acquisitions. All the main intracranial vessels were correctly depicted on the MIP images using conventional GRAPPA TOF and Sparse TOF with variable density Poisson sampling (Fig.2). The stenosis in the patient from Fig.2 was well represented on both GRAPPA TOF and sparse TOF images.

Discussion: Undersampling schemes with locally coherent sampling patterns can induce image artifacts. Increased incoherence in the sampling pattern should improve the performance of sparse MRI techniques (8). Using sparse TOF MRA with the variable density Poisson incoherent sampling pattern, it was possible to obtain robust, high-quality and artifact-free images with 45% shorter acquisition times compared to conventional TOF imaging with parallel imaging. This allowed the acquisition of high-resolution isotropic TOF MRA on a standard clinical scanner in just 3:15 min. Sparse TOF techniques promise shorter scan-times for currently long TOF examinations which may in turn reduce the risk of motion during the acquisition and hence contribute in making TOF more robust as well.

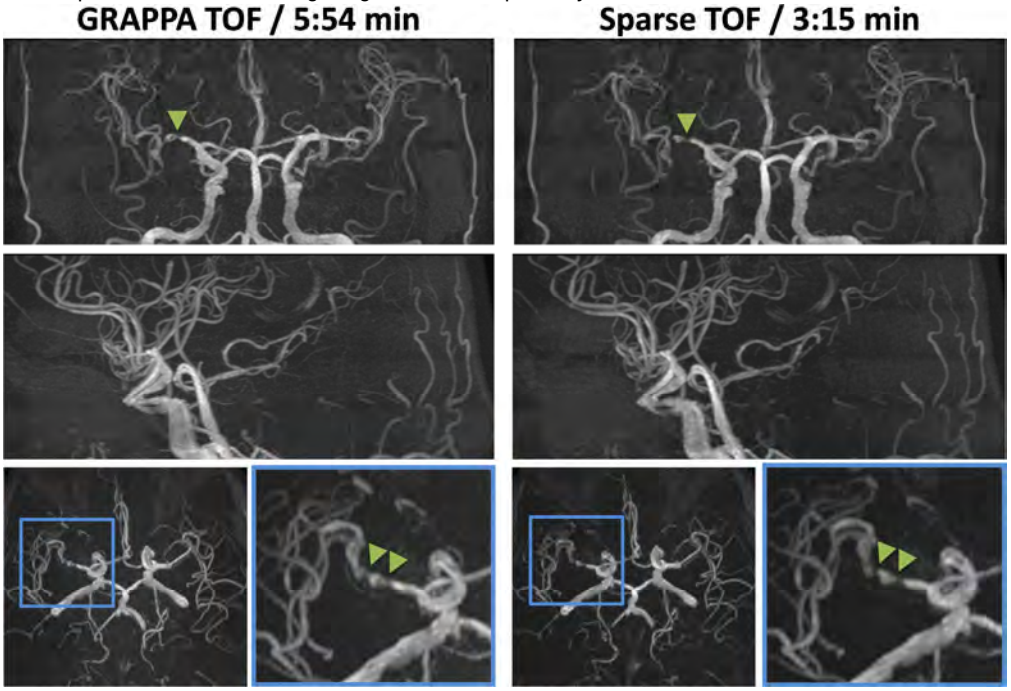

Fig.2: MIP images of conventional GRAPPA TOF vs. Sparse TOF with variable density Poisson sampling in a patient with stenosis (arrowheads). The reconstructed voxel size was 0.3 x 0.3 x 0.3 mm^3.

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