TOF Angiography in the human brain at 7T using 3D Parallel Excitation: Initial results

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INTRODUCTION. One of the main challenges in ultra-high-field imaging is the spatial inhomogeneity of transmit B1. In cerebral time of flight (TOF) angiography this inhomogeneity results in spatially varying background suppression and thus suboptimal contrast. Parallel transmission (pTX) [1,2] proved to be successful in providing homogeneous excitation in the human brain [3] by using independent RF waveforms on multiple transmit channels. So far, however, pTX methods have not been used at a large scale in clinical applications, and it remains to be demonstrated that this approach provides reliable and robust results when applied in clinical MR protocols. In this report we demonstrate the successful implementation of Spoke 3D RF pulses in multi-slab TOF angiography at 7 T.

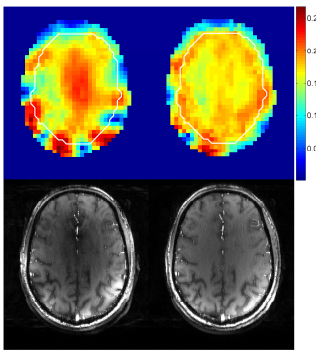

Fig.1. *Single Spoke (left) vs. 2-Spoke (right) 3D RF pulse. Bloch simulation of excitation profile (top row) and experimental images (bottom row). White curve: ROI for RF pulse design.*

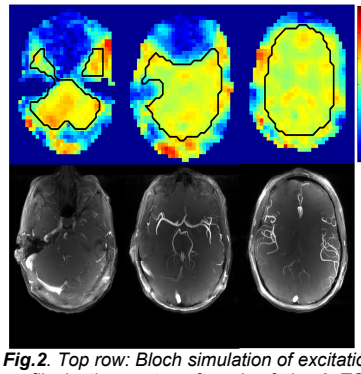

Fig.2. *Top row: Bloch simulation of excitation profile in the center of each of the 3 TOF slab with 2-spoke 3D RF pulses. Bottom row: MIP images of each TOF slab. Black curve: ROI for RF pulse design.*

METHODS. A 7T whole body MR scanner with an 8-ch TX Array (Siemens, Erlangen, Germany) was used to image healthy volunteers who signed an IRB-approved consent form. For signal transmission we used every other element of an elliptical 16-channel transceiver coil [4] while receiving signals on all 16 channels. Complex B1+ maps of the 8 channels were obtained using a fast multi-channel B1+ method [5], based on 5mm thick 2D GRE images acquired at the center of each TOF excitation 3D slab. 3D Spoke RF pulses based on filtered SINC-shaped RF subpulses with BWTP=4 were calculated in Matlab (The Mathworks) using nonlinear optimization [3] to optimize excitation homogeneity within a ROI which was manually drawn to cover all brain tissues within the slice. These 3D Spoke RF pulses were used with a TOF sequence modified to enable the use of 8-channel TX. It was determined in a first series of experiments that 2 spokes were sufficient to provide satisfactory excitation homogeneity, even in an axial plane located close to the longest head dimension along Y (Fig. 1). In the next series of experiments, TOF angiograms were acquired in three axial slabs of 50.4mm thickness with 52% overlap (excitation thickness 36mm). For each TOF slab, a 2-spoke 3D RF pulses was calculated, targeting a ROI drawn on the center slice of the slab (Fig. 2, black curve). Maximum intensity projection (MIP) images were generated from each slab datasets and, in axial view, for all slabs together. For technical reasons the reconstruction tool to merge TOF slabs could not be used with the pTX images, thus each slab is shown separately in sagittal and coronal views. Imaging parameters for pTX data: TR=33ms, resolution=0.67x0.67x0.7mm^3, GRAPPA=2 (PE), partial fourier=6/8 (SL).

RESULTS. Fig. 1 shows the impact of using 1 vs. 2 spokes in RF pulse design. The stronger B1+ observed in the center of the slice in Bloch simulation when using a single spoke RF pulse (top left) is consistent with the drop of signal experimentally observed in the center of the slice (bottom left), resulting from increased saturation at larger flip angle (T1 weight at very short TR). By contrast, Bloch simulations predicted a significant increase in spatial homogeneity when using a 2-spoke RF pulse design (top right). This was also confirmed experimentally (bottom right) with a much more homogeneous signal (acquisition parameters were identical except for the RF pulse design). Note that the receive profile of the coils, responsible for brighter signal in the periphery, was not removed from the images. Similar 2-Spoke RF pulses were used in a 3-slab TOF acquisition, shown in another volunteer. Bloch simulation of the excitation profile is shown in Fig. 2 (top row) in the center of each slab. The bottom row shows 24mm thick MIP images of the corresponding slabs. Again, the receive profile of the coil (brighter periphery) was not removed from the images. Figure 3 demonstrates the corresponding axial MIP image through the 3 slabs (72mm thickness) as well as coronal and sagittal MIP images of each slab (thickness 40mm). A good background signal suppression quality can be seen, which is highlighted in the plot in Fig. 3 (top right) which shows a horizontal profile of the sagittal MIP of the top slab (dashed line). The signal increase noticed on the edge can be explained by the receive profile of the coils. One can notice a residual signal modulation along Z in each slab, suggesting that acquiring B1+ calibration over multiple slices in each slab (instead of a single slice per slab) may potentially further improve slab excitation homogeneity by enabling a more accurate 3D RF pulse design. Using a RF subpulse with sharper slice profile could also be investigated.

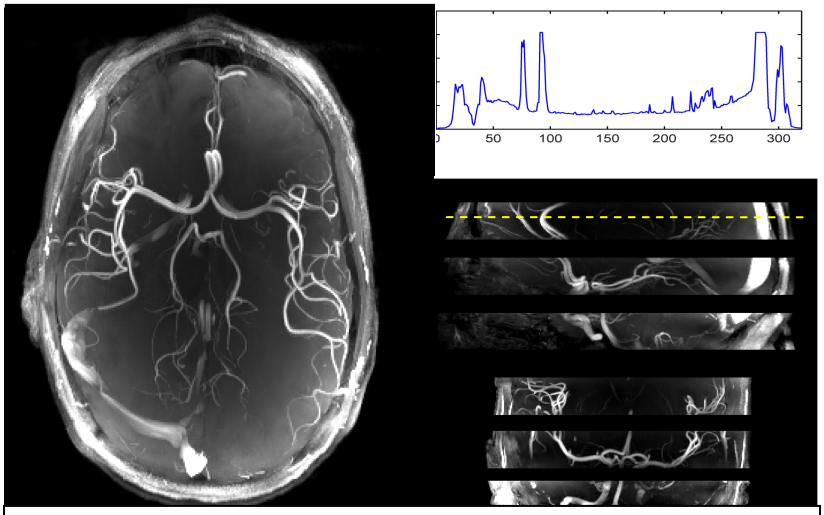

Fig.3 *Left: Axial MIP through the 3 TOF slabs. Right: Coronal (bottom) and sagittal (middle) MIP (40mm thick). Plot (top) showing the MIP profile along the dashed yellow line.*

DISCUSSION: We have demonstrated that TOF angiography can successfully be obtained when using multi channel 3D Spoke RF excitation in the human brain at 7T. Using 8 transmit elements, it was found that two spokes provided satisfactory excitation homogeneity with RF pulses designed for each TOF slab, resulting in efficient background signal suppression. Even though a complete background suppression was not expected in these preliminary data, which were obtained with very conservative settings with regards to SAR, without saturation or MT pulses and using an excitation flip angle smaller than 20° (which is not optimal for TOF contrast), these successful results strongly suggest that pTX 3D RF pulses have the potential of improving image quality in clinical MR protocols.

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REFERENCES [1] Katscher et al. MRM 2003;49, 144-50; [2] Zhu et al. MRM 2008;51:775-84 [3] Setsompop et al. MRM 2008;60:1422-32; [4] Adriany et al, MRM 2008,59:590-597 [5] Van de Moortele et al. Proc. ISMRM 2009; 367