

# Whole brain High Resolution T2w 3D TSE at 7Tesla with a tissue specific non linear refocus pulse angle sweep; initial results.

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## Introduction:

Spin Echo (SE) is ubiquitous in the assessment of brain pathology, with Turbo Spin Echo (TSE) as its preferred implementation for optimal Signal-to-Noise (SNR), efficiency and shorter scan times at high resolution. The implementation of 3D techniques has further improved the sensitivity and specificity by reducing partial volume effects compare to 2D in detecting sub-millimeter lesions. Successful implementation of 3D T2w TSE sequences has been reported for 3T and lower field strengths [1]. At 7T, the implementation of 3D T2w TSE is less straightforward [2] due to SAR constraints, high sensitivity to susceptibility and motion, short T2 components and RF receive and transmit in-homogeneity. The aim of the present study is to develop a high resolution 3D T2w TSE sequence with good T2 contrast and high SNR. The sequence should cover the whole brain, capable of intra-hippocampus segmentation and the detection of sub-millimeter lesions.

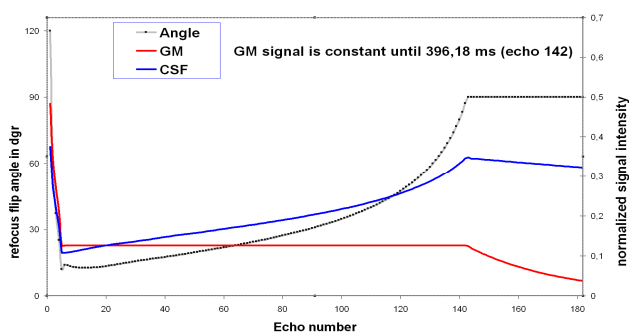


Figure 1, Simulation tissue specific refocusing pulse angle sweep

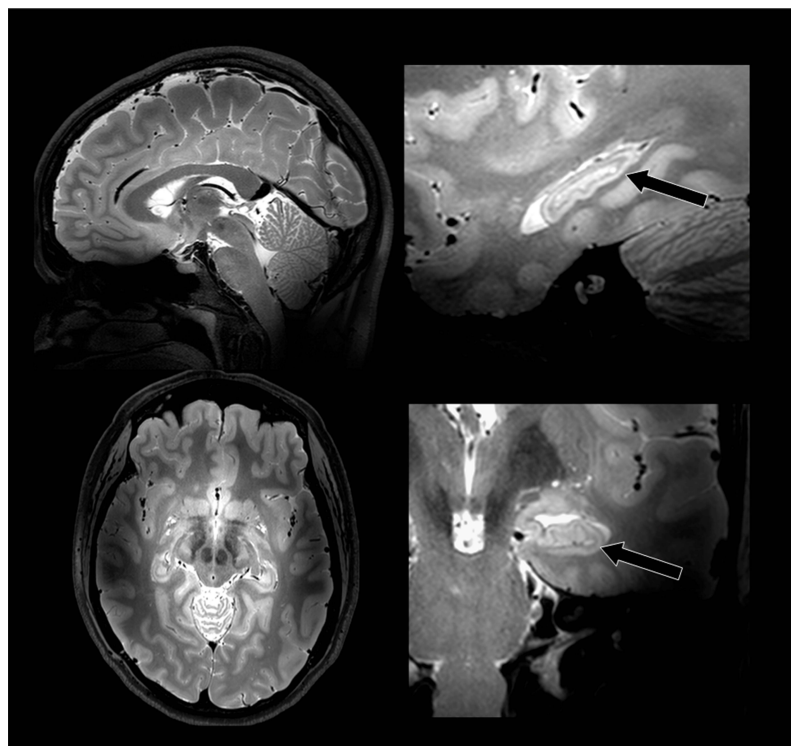


Figure 2. Top row: sag. source images Bottom row: trans. / cor. reformat

## Methods:

Imaging was performed on a 7T scanner (Philips Healthcare) using a 16 channel receive head coil with single channel volume transmit coil (Nova Medical). A sagittal T2w 3D TSE sequence covering the whole brain was implemented with the following scan parameters; isotropic voxel size of  $0.7 \times 0.7 \times 0.7 \text{ mm}^3$ , interpolated by zero-filling to  $0.35 \times 0.35 \times 0.35 \text{ mm}^3$ , FOV  $250 \times 250 \times 190 \text{ mm}^3$ , 543 slices, TR/TE  $\sim 3300/255 \text{ ms}$ , turbo factor 182, echo spacing 2.79ms, 2D-SENSE factor 6, total scan time  $\sim 9:40 \text{ min}$ . A tissue specific refocusing pulse angle sweep [3] was used to reduce SAR and to optimize image contrast. Two signal averages (NSA) were used to reduce FID artifacts by alternating the phase by 180 degrees between first and second average. To reduce the CSF ghost artifacts, cardiac gating was introduced in combination with an anti Driven Equilibrium (anti-DRIVE) pulse, consisting of an inverse refocusing sweep to the end of the echo train followed by an  $+90^\circ$  pulse on the last echo top, which reduces the CSF signal level. To stay within the SAR limits a repetition time of 3 to 5 heart beats was chosen, depending on the subjects heart rate. Over-tipping of the excitation pulse angle by  $130^\circ$  was used to level out  $B1^+$  in-homogeneities over temporal lobes and center of the brain. Five subjects have been scanned 2 females and 3 males, ranging in age from 21 to 77 years with a mean of 44.

## Results:

The in vivo experiments show high quality isotropic 3D T2weighted images (Figure 2) that can be used for Multi Planar Reformat (MPR) and Minimum Intensity Projection (MinIP) for black-blood arterial angiography (not shown). The implemented sweep was simulated under the assumption of a homogeneous  $B1^+$  and optimized for GM T1/T2 2130/55ms [4] to give a flat transverse magnetization response over  $\sim 400 \text{ ms}$  of the echo train. After this point the refocusing angle was fixed to a given maximum  $90^\circ$ . This all results in a refocus pulse angle sweep with a nominal angle of  $12^\circ$  and a maximum of  $90^\circ$  (Figure 1), and an equivalent TE of 60ms. Anti-DRIVE reduces the hyper intensive signal of Cerebral Spinal Fluid (CSF) responsible for the main cause of ghosting artifacts. The over-tipping excitation angle compensates for a large part the transmit/receive in-homogeneities caused by standing wave properties at 300 mHz, whereas the pseudo steady state reached over the long TSE train is relatively insensitive for  $B1^+$  variations. The refocusing pulse angle sweep makes the sequence relatively sensitive for flow in general and CSF in particular seen at the base of the brain around the basilar artery (Figure 2).

## Conclusion:

High resolution T2w 3D TSE images with high image quality and integrity can be obtained at 7T. Applying a tissue specific refocusing angle sweep, reduces SAR and improves SNR and CNR. This technique provides, next to a robust basic T2w scan, a new diagnostic window for hippocampus sub-segmentation and the detection of sub-millimeter cortical and/or sub cortical lesions in future clinical studies. Multi Transmit and or more advanced RF pulse shapes that are less sensitive for  $B1$  variation may be investigated for further improvement for the entire brain anatomy. For now, the technique described suffices to study subtle anatomical changes in the hippocampus, an marker for the onset of degenerative processes in the brain.

## References:

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- [3] Hennig J, et al, Multi echo sequences with variable refocusing flip angles: optimization of signal behavior using smooth transitions between pseudo steady states. *MRM volume 49*
- [4] Rooney W.D. et al, Magnetic field and tissue dependencies of human brain longitudinal  $1H_2O$  relaxation in vivo. *MRM vol. 57*