Quiet T1-weighted head scanning using PETRA

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Introduction: In conventional MRI examinations, fast gradient switching leads to high acoustic noise. High acoustic noise is one of the main reasons for patient discomfort or restlessness. Ultra-short echo time sequences like the zTE- [1], SWIFT- [2] or PETRA sequence [3,4] only require very limited gradient activity and allow for inaudible scanning. However, contrast in these sequences is limited unless pre-pulses are used [5].
In this work, we investigate the generation of T1 contrast with the PETRA sequence. We show that T1 contrast comparable to the MPRAGE sequence [6] can be achieved in inaudible scans without changes to scan time or spatial resolution.

Materials and Methods: In the ultra-short echo time sequences zTE, SWIFT and PETRA, gradients are already switched on before the excitation pulse, as shown in Fig.1. At the end of each repetition, the gradient strength is altered. Because the changes in gradient strength are incremental and the required slew rate is extremely low (e.g. < 5 T/m/s in PETRA), only negligible vibration and deformation of the gradient coil is created. As a result of this, typically only residual noise due to TX-RX switching may become noticeable in these sequences. Due to the ultra-short echo time, image contrast is given by the steady state and in the range of PD- to T1-weighting. Pre-pulses can be used to modify image contrast.
We use a 180° inversion pulse to enhance the T1 contrast in the PETRA sequence. Comparable to the MPRAGE sequence, this inversion pulse is only applied every n^{th} repetition. After the pulse, no data is acquired for the inversion time *TI*. Additionally, before the inversion pulse is applied, no acquisition or excitation is performed during the waiting time *TW*, as shown in Fig. 2a. Figure 2b shows the development of the longitudinal magnetization after the inversion.
Simulations of the expected signal from grey and white matter were performed with MATLAB. Different combinations of *TI*, *TW* and *n* were evaluated for a repetition time *TR* = 3 ms and a flip angle of 6°. The PETRA sequence was implemented on a 3T clinical scanner (MAGNETOM Skyra, Siemens, Erlangen). In-vivo scans were performed on healthy volunteers after informed consent with the PETRA and the MPRAGE sequence.

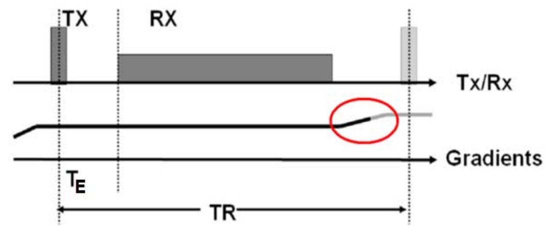

Fig. 1: Sequence diagram of the PETRA sequence.

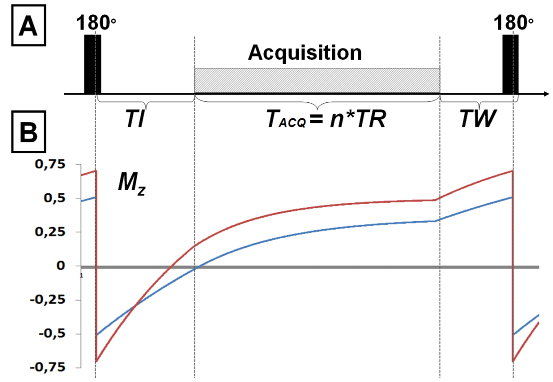

Fig. 2: a) Schematic timing diagram of one inversion cycle. b) Development of the longitudinal magnetization M_z during the inversion cycle.

Results: The simulation of *TI, TW* and *n* show, that better SNR is reached if *TI>>TW,* and better CNR is reached if *TW* is in the range of *TI.* Contrast can be increased with increased *TW*, but longer scan times would be needed.
Figure 3 shows in-vivo head images acquired with an MPRAGE (a), and PETRA (b) with *TI* = 500 ms, *TW* = 400 ms and *n* = 400 . Scan time in both scans was around 5 minutes with an isotropic resolution of 1.1 mm. The contrast–to-noise ratio between grey and white matter was 24 (MPRAGE) and 21 (PETRA). SNR of grey/white matter was 54/30 (MPRAGE) and 54/33 (PETRA). While acoustic noise in the MPRAGE sequence exceeded 95 dB(A), PETRA was measured at 3 dB(A) above the background noise using the 32 channel head coil and not measurably louder than the background noise using the body coil.

Discussion: In this work, we investigated the contrast characteristics of the PETRA sequence for T1-weighted head scanning. Simulations of different parameter settings show, that either higher SNR or CNR or a compromise between the two can be chosen. In the MPRAGE sequence, center k-space lines are acquired at a time after the pulse, that enables the best CNR between grey and white brain matter and the best SNR. This is not possible with the zTE- or SWIFT approach, because in these sequences, every repetition acquires a radial half projection through k-space and a systematic reordering of k-space center is not possible.
Since PETRA acquires the k-space center separately from the radial part, different reorderings are possible. Because the k-space center is acquired pointwise, the reordering has additional alternatives compared to MPRAGE. To optimize contrast and SNR, we therefore use a reordering that acquires the absolute k-space center points after the very first inversion pulse, where the steady state is not yet formed and the spin system is completely relaxed.
Image comparison to an MPRAGE scan show that PETRA scans can come close to the CNR or SNR achieved in MPRAGE, while the PETRA scan is almost silent. Due to the ultra-short echo time, bone matter and signal near susceptibility interfaces, e.g. near sinuses, is less blurred in PETRA. A detailed analysis of image differences and potential new diagnostic information is a matter of ongoing investigations.
In conclusion we have shown that inaudible T1-weighted head scanning is possible using PETRA. This improves patient comfort and scan acceptance, especially for geriatric or pediatric patients. Good image quality and contrast comparable to MPRAGE scans are achieved without prolonging scan time or lowering resolution. No hardware changes are required for the PETRA sequence.

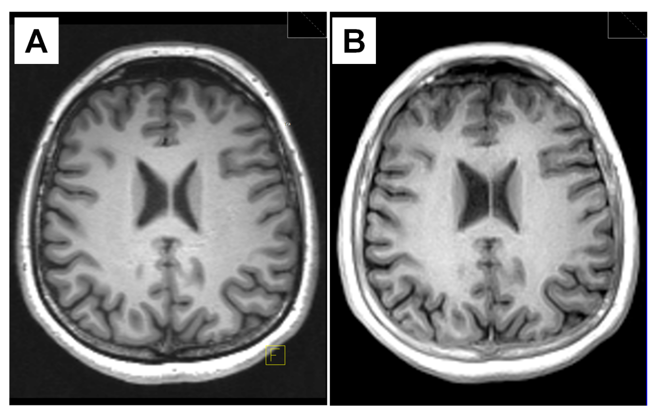

Fig. 3: a) MPRAGE scan, b) PETRA scan, see text.

References: [1] Weiger et al. MRM 2011; [2] Idiyatullin et al. JMR 2006; [3] Grodzki et al. MRM 2012; [4] Grodzki et al. JMR 2012; [5] Chamberlain et al. Proc. ISMRM 2011; [6] Brant-Zawadzki et al. Radiology 1992