Ultra short Echo Time Imaging using Pointwise Encoding Time reduction with Radial Acquisition (PETRA)

D. M. Grodzki[1,2], P. M. Jakob[1], and B. Heismann[2]

[1]Department of Physics EP5, University of Wuerzburg, Wuerzburg, Bavaria, Germany, [2]Magnetic Resonance, Siemens AG, Erlangen, Bavaria, Germany

Introduction: Sequences with ultra short echo time (TE) enable new applications of MRI, including bone, tendon, ligament and dent imaging. In this work a sequence is presented that achieves the shortest possible TE given by TX/RX switching time and gradient performance of the MR Scanner. In PETRA (Pointwise Encoding Time reduction with Radial Acquisition) outer k-space is filled with radial half-projections whereas the centre is measured single pointwise on a Cartesian trajectory. This hybrid sequence combines the features of single point imaging with radial projection imaging. No hardware changes are required.

Materials & Methods: The radial part of the sequence runs similar to projection imaging methods like Zero-TE [1] or WASPI [2]. After the gradient ramp-up, a hard low-flip-angle pulse (10µs, 4°) is applied and readout is started at the echo time t=TE_1, see Fig. 1 a). As encoding starts at t=0, k-space points in the centre of k-space are missed, as indicated by Fig. 1 c). In [1], these points are filled by algebraic reconstruction, while in [2] a few more radial spokes with lower gradient strengths are acquired to fill at least parts of the gap with measured data.
In our approach, the gap is completely filled with exact measured Cartesian k-space points using single point imaging like RASP [3] or SPRITE [4], see Fig. 1 b). During reconstruction, both parts of the sequence are combined and a gridding algorithm is applied for the radial part. A second echo can be acquired by changing the gradients polarity at the end of the first readout.
Compared to the UTE sequence [5], where gradients are ramped up after excitation, PETRA offers shorter encoding times over the whole k-space, see Fig. 2. This enables higher resolution for tissue with very short T2, as the signal decay during the readout is less strong. PETRA as well as BLAST and WASPI are 3D-only methods, while with UTE slice-selection is possible. PETRA has very low demands on gradient switching times and is not disturbed by gradient-imperfections like eddy-currents and time delays. This can be a major problem for UTE-imaging. If desired, fat-suppression or T2 weighting prepulses can be added to the sequence.
PETRA was implemented and tested on a 1.5T whole body system. The minimum echo time was limited only by the smallest possible time between excitation and data sampling, which was 50µs in this case.

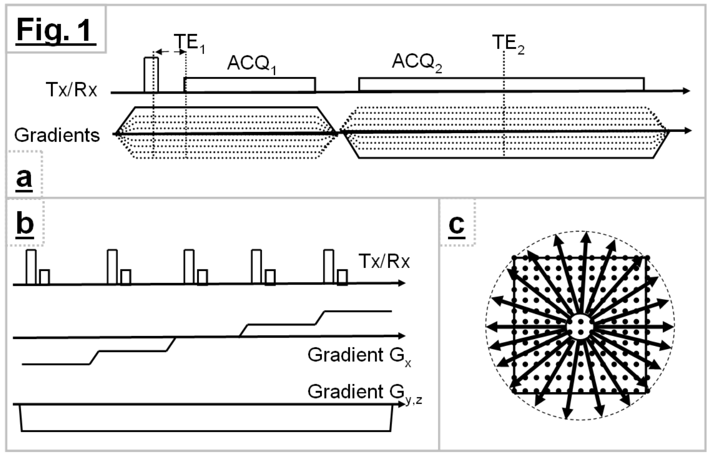
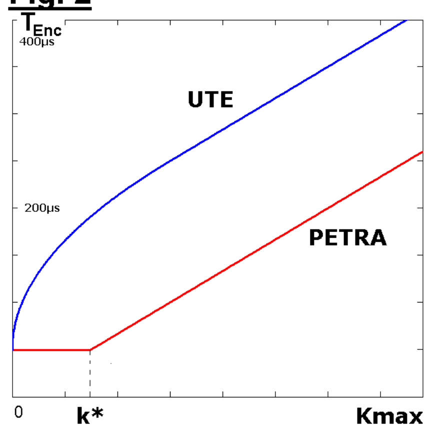


Fig. 2



Results / Conclusion: PETRA shows good SNR for tissue with short T2 and good image quality overall. Contrast is steady-state driven and is either proton density or T1 weighted. Image series with two echos and the subtraction of the two images offers good visibility of short T2 tissues only. Figure 3 shows an image series of the wrist of one of the authors, with a) TE_1=50 µs, b) TE_2 = 4.6 ms and the subtraction of a) and b) in c). Hands ligaments as well as wrist bones are visible.
In conclusion, the hybrid solution of radial projection imaging and single point imaging is feasible. It combines the advantages of both approaches and avoids problems of the UTE approach. The shortest possible TE achieved is only limited by hardware switching times. We have shown that PETRA is able to depict tissue with short T2 in vitro as well as in vivo. No hardware changes or additional hardware requirements are needed. Images with a 1 mm resolution in a 256^3 matrix can be imaged in as fast as 2 to 5 minutes, including two series with very short and longer TE. These features might improve e.g. orthopedic MR imaging as well as MR-PET attenuation correction.

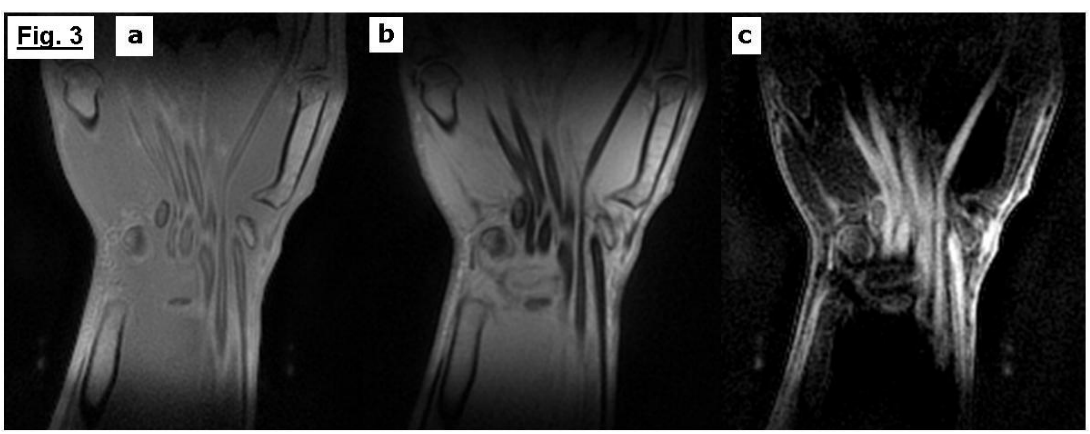


Fig. 3: Coronal PETRA wrist image series. 50000 radial spokes, α = 4°, isotropic imaging matrix of 256^3 with a resolution of 0.78 mm. Spoiling was activated, TR = 8.55 ms, acquisition time TA = 10 min 14'. a) TE1 = 50µs, b) TE2 = 4.6 ms, c) subtraction of a) and b).

References: **[1]** S. Hafner. MRM 1994;12:1047-1051 , **[2],** Y. Wu et al. MRM 2007;57:554-567 , **[3],** O.Heid et.al.Abstracts of the 3rd SMR annual meeting, p.684, (1995) , **[4]** B.J.Balcom, JMR, Series A 123, 131-134 (1996) , **[5]** D.J. Tyler et al. JMRI 2007;25:279-289