Center-Acquisition-at-Partial-Ramp Imaging (CAPRI) for the Reduction of Off-Resonance and T2 Induced Blurring Artifacts

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Background: In UTE imaging the k-space center is acquired during ramp-up of the read-out gradient. Image quality is affected by the distortion of the trajectory due to eddy currents and gradient / system delays. Furthermore, the reduced bandwidth during ramp-sampling and the slow acquisition of the center part of k-space yields a fast (quadratic) T2-decay. Where trajectory distortions and system delays can be corrected for [1], the image blur due to the fast T2 decay in the k-space center is inevitable. In clinical scanners, front-end switching time constraints currently limits the minimal TE to 50µs or even higher. In this manuscript a modified UTE technique is introduced in which the dead time is used for application of a small prephasing gradient for minimization of the required ramp sampling.

Methods and Materials: In UTE imaging the ramp-sampling leads to a quadratic T2 decay during the acquisition of the k-space center. By applying a small prephasing gradient the k-center is sampled at a higher read-out gradient and hence much faster than in conventional UTE technique. The faster sampling causes less T2 decay during k-center sampling with a concomitant reduction of image blur due to T2 and off-resonance effects.

Two different approaches have been investigated: start of the data acquisition at I) the minimal possible echo time TE_{min}, which correspond to the dead time of the frontend, and II) at $TE_{min} < TE_{ramp} <= TE_{plateau}$. For $TE = TE_{plateau}$ the acquisition starts simultaneously with the start point of the gradient plateau (see fig.1). Otherwise, data acqusition starts already before k-space center coverage and the acquired echo can be used to compensate e.g. for system delays.

Simulation of the Bloch-equation was performed to analyze the expected blur caused by T2 relaxation in the different imaging techniques. Simulation parameter were as: $TE = 0.24$, $T2 = 0.5$ms, $T_{acq} = 0.6$ms and $t_{ramp} = 0.15$ms.

All imaging was performed on a 3T whole body imager (Achieva, Philips Medical, Netherlands) with a gradient slew rate of 200mT/m s and a readout gradient strength of 20mT/m. For I) TE_{min} resulted to 50µs yielding an initial gradient strength of 4mT/m while scanning the k-.space center. For II) the current setup, $TE = TE_{plateau}$ resulted to 250µs. For direct comparison of the modified technique with the conventional UTE technique a constant timing of TE / TR = 0.37µs / 5.5ms was used for resolution phantom as well as for the in vivo experiments. In all cases, a mono-exponential eddy current response was applied for trajectory correction. Furthermore, additional gradient delays were compensated by automatic identification of the maximal FID/echo signal.

Results: Simulation results (fig. 2) show a clear reduction of the image blur for the modified approach. The resolution phantom measurements (fig.3) proof the excellent performance of the trajectory correction method for the UTE technique. In vivo results (fig. 4) revealed improved image sharpness and somehow improved image contrast for the modified techniques. Best results were obtained with starting the sampling on the gradient plateau.

Discussion: Sampling of the k-center at higher gradient strengths leads to less blur and improved contrast compared to conventional UTE imaging. Using the minimal possible echo time can be applied for image quality improvement without sacrificing signal intensity for short T2 components. Further image quality improvements can be realized by accepting some signal intensity reduction of the short T2 species. This should be possible in cases of T2 values of a few hundred microseconds. Applying this extreme asymmetric sampling approach further enables the automatic correction for echo top shifts as published earlier for conventional radial sampling techniques [2].

References: [1]Duyn et. al. JMR 1998 (132;150-53), [2] Rasche et. Al. MRM 19
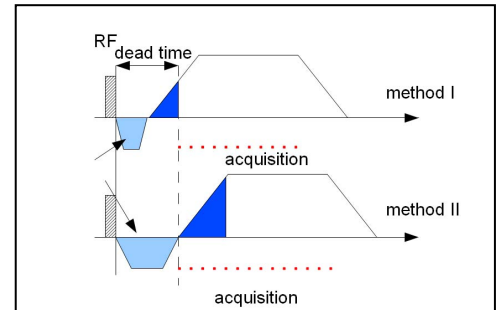
Fig.1 CAPRI: prephasing gradient is used to acquire k-space center at higher gradient strength.
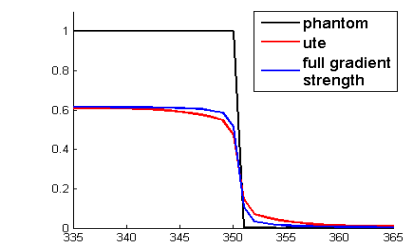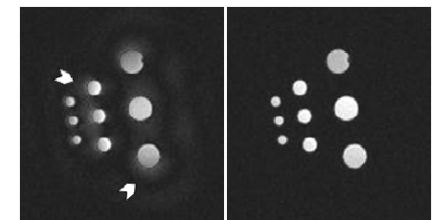

Fig.2 Simulation of T2 induced blurring.

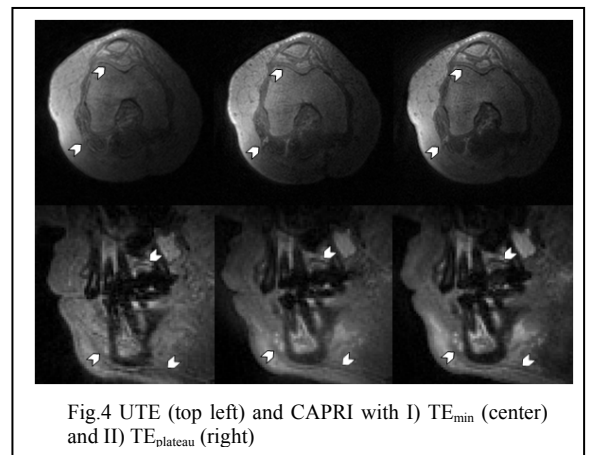Fig. 3 CAPRI (TE = $TE_{plateau}$) without (left) and with (right) delay compensation.

Fig.4 UTE (top left) and CAPRI with I) TE_{min} (center) and II) $TE_{plateau}$ (right)