k-TE GRAPPA for Rapid Abdominal R2* Mapping

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Introduction R2* measurements have proven useful for a number of abdominal imaging applications [1, 2]. The commonly used multiple-GRE (MGRE) sequence collects a train of echoes after each excitation thereby permitting the reconstruction of separate images at each TE and subsequent derivation of R2* maps. However, spatial resolution and overall volumetric coverage often remains limited due to breath-hold requirements. Based upon an extension of previously proposed *k-t* GRAPPA parallel imaging methods [3] we recently developed a *k*-TE GRAPPA approach to reduce MGRE scan times. The purpose of our study was to compare *k-TE* GRAPPA to conventional GRAPPA and view-sharing approaches for MGRE R2*-mapping in phantoms and healthy volunteers.

Methods *k*-TE GRAPPA *k*-t GRAPPA exploits correlations in *k*-space and time to reduce residual parallel imaging artifacts [3]. Reconstruction is similar to GRAPPA but involves additional contributions from earlier and later sampled *k*-space lines to the coefficient fitting parameters. For MGRE we sought to exploit correlations between *k*-space and echo-time dimensions therefore dubbing the technique '*k*-TE' GRAPPA.

Data Acquisition Imaging was performed using a 1.5T clinical MRI scanner (Siemens Magnetom Sonata) with 6 channel anterior and posterior array coils. MGRE sequence was modified to sub-sample *k*-space along the k_y dimension while alternating sub-sampling positions along the TE dimension (i.e. for acceleration rate = 2, odd k_y sampled for odd echo numbers and even k_y for even echo numbers). The latter alternation was accomplished with the application of phase-encoding gradients between adjacent read-outs. MGRE parameters: TR/TE=60/3-40ms, 30° flip-angle, 630Hz/px BW, 5mm slices, ETL=16. We performed additional acquisitions with spatial-spectral water excitations (WE) to investigate the impact of in- and out-of-phase fat signals upon view-sharing and *k*-TE methods. Acquisitions were repeated at *k*-TE GRAPPA acceleration rates 1, 2, 3, 4, and 5. We separately reconstructed images at each TE using view-sharing, GRAPPA, and *k*-TE GRAPPA approaches. Voxel-wise linear fitting to produced R2* maps from each acquisition. *Phantom studies:* $MnCl_2$ –doped saline bottles were suspended in a peanut oil bath providing phantoms with wide ranging R2* and exterior ring representative of fatty tissues. *In vivo studies*: Axial and coronal abdominal MGRE scans were performed in 7 healthy volunteers according to IRB-approved study protocol.

Data Analysis For both phantom and volunteer studies, we calculated the artifact power (AP) at each TE for view-sharing (VS), GRAPPA, and *k*-TE GRAPPA approaches by comparison to fully sampled MGRE datasets. We measured mean R2* measurement error at each rate (medulla and liver ROIs). AP and R2* measurement error from the *in vivo* studies were compared using ANOVA with Tukey post-hoc correction (α=0.05).

Results Phantom Initial comparisons revealed that VS was significantly more sensitive to fat in/out-of-phase effects (>AP at each TE) than *k*-TE and WE yielded reduced AP for both VS and *k*-TE approaches (**Fig. 1A**). As expected for each of the three approaches AP increased with increasing R2* and TE due to more rapid signal decay (**Fig. 1B**). At each of the acceleration rates *k*-TE R2* measurements were more accurate (lower absolute error) than VS and conventional GRAPPA approaches (**Fig. 1C**).

In vivo Similar to our previous phantom studies, we found that AP was significantly reduced using water-excitation as opposed to conventional RF excitation methods. At rate=2 VS, GRAPPA, and *k*-TE GRAPPA offered similar performance (no significant difference in AP) while at all higher rates (i.e. rates>2) *k*-TE GRAPPA reduced AP and improved overall image quality compared to both alternative approaches ($p<0.05$). *In vivo* R2* maps for a representative volunteer study are shown in **Fig.2**. At acceleration rate=2 there was generally no discernable differences between the three approaches. However, when proceeding to higher rates, we note increased artifact levels for conventional GRAPPA R2*-maps and significant spatial blurring within VS maps compared to *k*-TE GRAPPA.

Conclusion *k*-TE GRAPPA is an effective parallel imaging method to accelerate MGRE R2*-mapping. *k*-TE GRAPPA reduced artifact levels and provided more accurate R2* measurements compared to VS and GRAPPA approaches. *k*-TE GRAPPA offers the potential to reduce breath-hold times and/or increase spatial resolution or coverage. Future studies will focus on 3D volumetric and clinical applications.

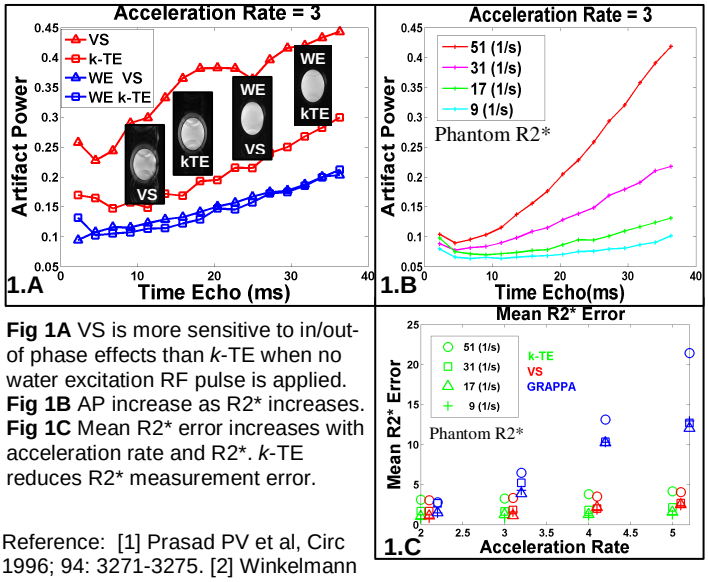

Fig 1A VS is more sensitive to in/out-of phase effects than *k*-TE when no water excitation RF pulse is applied. **Fig 1B** AP increase as R2* increases. **Fig 1C** Mean R2* error increases with acceleration rate and R2*. *k*-TE reduces R2* measurement error.

Reference: [1] Prasad PV et al, Circ 1996; 94: 3271-3275. [2] Winkelmann S et al, JMRI 2006: 2006; 24:939-944. [3] Huang F, 2005; 54: 1172-1184.

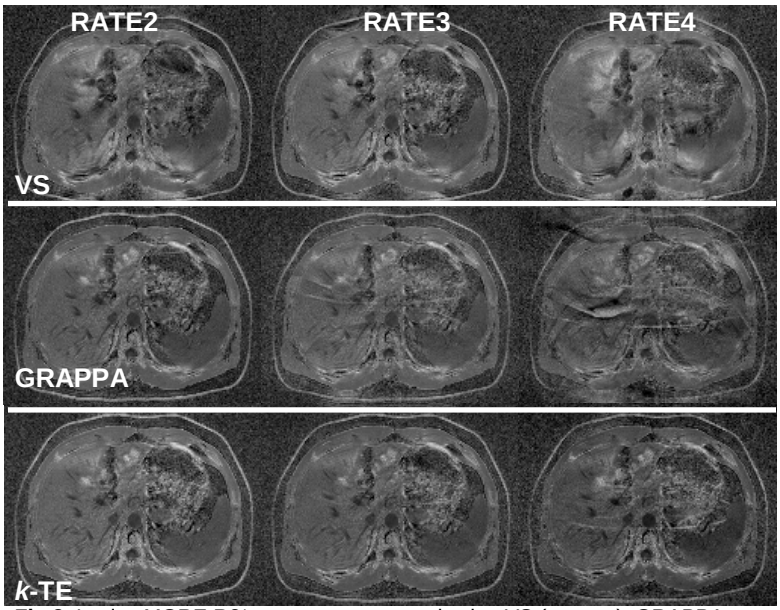

Fig 2. In vivo MGRE R2* maps reconstructed using VS (top row), GRAPPA (middle), *k*-TE GRAPPA (bottom) at acceleration rates 2, 3, and 4 (left to right). *k*-TE GRAPPA reduced artifact levels and avoided spatial blurring.