COntrast Manipulating MIXed kspace COMMIX CAPRI / UTE for ultra short T2* mapping using multiple echo times within a single k-space data set

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Purpose: Ultrashort echo-time T2* (UTE-T2*) mapping is a quantitative MRI technique to detect changes in tissues with very short T2* values. T2* values are calculated pixel-by-pixel from a series of UTE MRI images with varying echo times (TEs). This approach is very time consuming since one image for every echo time has to be acquired. This article presents an new ultra short T2* mapping approach using a COntrast Manipulating MIXed kspace (COMMIX) CAPRI or UTE sequence for substantial reduction of scan time by acquiring k-space data using miscellaneous echo times for individual profiles (related to KWIC)[1].

Methods and Materials: The approach is based on redundant data information in the k-space center due to its intrinsic oversampling in radial acquisition schemes. K-space data is acquired using **n** miscellaneous echo times for individual profiles (Fig1) and **n** images are reconstructed using n single TEs ($TE_{eff} = TE_{k<k_{\mathrm{COMMIX}}}$) for the k-space center. k_{COMMIX} defines the maximum radius for the inner part of k-space which fulfills the nyquist criteria for maximum distance ($d = \Delta k$) bewtween adjacent points :

$$k_{\mathrm{COMMIX}} = \frac{\Delta k\sqrt{N/4\pi}}{\sqrt{n}}$$

n: replacement factor number of TEs/Scan
N: number of profiles for full sampled k-space

While the inner part contains always the data with one specific TE to ensure the desired weighting, the outer part of k-space ($k_{\mathrm{COMMIX}} \le k \le k_{max}$) is filled with data acquired with different TEs to reduce aliasing artefacts due to undersampling.

Due to the lower sampling density in k-space center the SNR for mixed k-space with equidistant sampling in readout direction (cf = 1) results in:

$$SNR_{\mathrm{COMMIX}} = \sqrt{\frac{1 + (1-\frac{1}{\sqrt{n}}) * (n\text{-}1)}{n}} SNR_{\mathrm{full\ sampled}}$$

All data were acquired applying conventional UTE imaging sequence (capri factor = 0) on a clinical 3-Tesla whole body MRI (Achieva, Philips Medical, Best, Netherlands). The MRI protocol included 6 UTE scans with TE[µs] as 140; 250; 500; 750; 1130; 1240; 1490; 1740, constant TR of 6.5ms, FOV of 150mm^3 and a resolution of 1mm^3. For comparison of SNR and T2* values different images were reconstructed from the data sets (fig.2):

I. fully sampled for each TE
II. undersampled using every n-th profile (reduction of scan time without aliasing compensation)
III. fully-sampled with reduced sampling density in k-space center
IV. COMMIX with outer k-space filled from data acquired with different TEs

Data analyses: T2*-decay curves obtained from the rubber phantom (fig.3) and reconstructed from the different approaches are shown in fig 4. Data points were fit to a mono-exponential decay model. Signal to Noise values were calculated as the ratio of the mean intensities of the water phantom and the standard deviation of the background. SNR values were calculated as average signal over all 6 echo times and referenced to the fully sampled data.

Results and Discussion: The T2* values obtained from fully sampled data results as 941±112µs and 655±58µs respective for rubber 1 and 2 (fig. 3). The COMMIX approach yielded T2* values of 949±105 / 641±139µs ($n = 2$), 943±125 / 660±129µs ($n = 3$) and 881±154 / 857±433 µs ($n = 4$). SNR analysis revealed a slight reduction for mixed k-space (case IV) compared to case III but much higher compared to the theoretical values. The higher standard deviation in SNR for the former case may be attributed to the k-space mix with different TE values and therefore with further or less decayed signals.

Conclusion: COMMIX is an effective approach for ultrashort T2* mapping. Sharing high-frequency data acquired at different echo times enabled scan time reductions of at least 66% for rapid T2* mapping without compromising image or T2* value fidelity. SNR values in the COMMIX approach were comparable to full data sampling. The impact of COMMIX at the T2* values for structures sizes close to the resolution limit remains to be further investigated.

References: 1. Song et. al., Magn Reson Med.;44(6):825-32(2000);

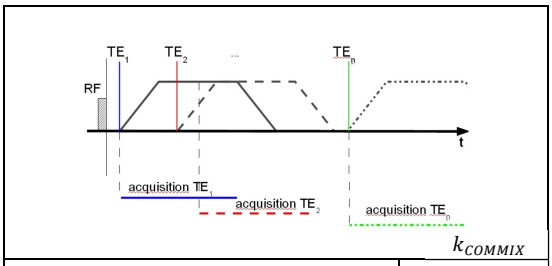
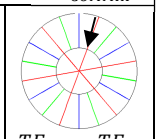


Fig.1: COMMIX sequence(top): multiple TEs are acquired during a single kooshball experiment. Adjacent k-space profiles sampled with different TEs(right). Images were resonstructed with one specific $TE = TE_{eff}$ for $k < k_{\mathrm{COMMIX}}$.



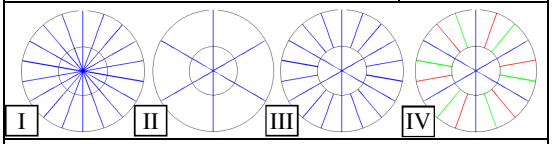


Fig.2: k-space filling for n = 3; a) full sampled b) every n-th profile c) COMMIX (same TE) d) COMMIX (mixed TEs)

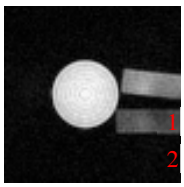
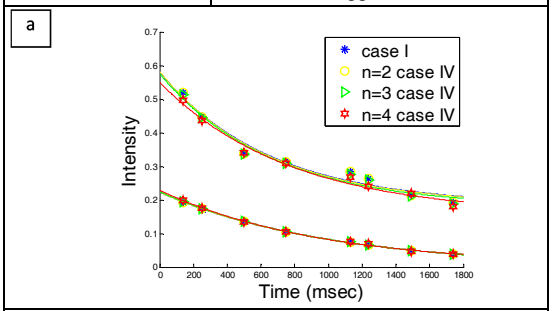
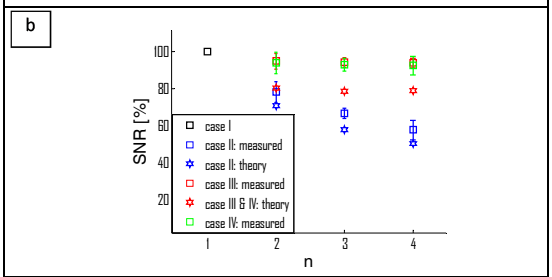


Fig.3: water phantom (ball) for SNR measurements and rubbers for comparision between ultrashort T2*approaches

Fig.4(bottom): Results image intensity versus TE and the fitted T2*decay for rubber 1 (lower curve) and rubber 2 (upper curve)





(b) relative SNR refered to full sampled image