Ultra high spatio-temporal resolution dynamic tumour imaging using EC TRICKS and parallel imaging

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Introduction: Dynamic contrast enhanced (DCE) MRI has found widespread clinical acceptance as the method of choice for detection of cancer. The sensitivity of MRI to tumors is high but the reported specificity has been variable due to the compromises that have to be made between temporal and spatial resolution, and fat saturation (in the case of breast and liver). Various methods like keyhole imaging [1] and RIGR [2] have been proposed to improve the data acquisition rates for dynamic imaging. TRICKS [3] has been successfully used in angiography to provide time-resolved 3D images. We investigated the use of elliptical centric (EC) TRICKS with parallel imaging (ASSET) for dynamic contrast enhanced tumour imaging to improve temporal and spatial resolution. The use of elliptical centric k-space ordering will help reduce motion and pulsatile flow artifacts. Simulations were performed to model the accuracy of the signal enhancement curves obtained using TRICKS, as the initial slope is an important indicator of tumour malignancy [4]. We tested this approach by collecting breast images from volunteer subjects. A novel fat suppression technique that is compatible with elliptical centric view ordering was used eliminating the need for data subtraction that can lead to errors especially when imaging the liver and the abdomen.

Methods: All simulations were carried out in MATLAB. A 3D model with two types of tumours (a 6 mm diameter tumour and a rim enhancing tumour with 6 mm diameter) was used to generate k-space data. The tumours were made to enhance with an early enhancement rate of 150-200% in the first minute representing aggressively enhancing tumors [4]. Partial data were generated for each temporal phase by sub-sampling and reconstructed using TRICKS and compared with the full k-space reconstructed images. The signal enhancement curves were computed using ROI values from the tumours. For the simulation data, this was compared with the "true" values (full k-space reconstruction). Volunteer subjects were scanned after informed consent on a 1.5 T GE Signa Excite scanner. A 4- channel phased array breast coil was used with the subject lying in a prone position. An elliptical centric 3D spoiled GRE sequence was used for imaging the breast bilaterally in an axial plane. The scan parameters were as follows- acquisition matrix 384x320x24, bandwidth $\pm$ 62.5 KHz, TE/TR 1.6ms/4.5 ms, slice thickness 3 mm, FOV 38x32 cm, flip 20º. We used a novel EC compatible fat saturation sequence (details in abstract submitted for ISMRM 2005) for effecting fat suppression. Unlike conventional fat suppression methods, the play-out rate of the fat suppression pulses was varied as a function of k_r, the distance from the center of k-space. This minimized ghosting by eliminating modulation of fat signal in the center of k-space and provided optimal fat suppression with no increase in scan time over the conventional fat saturation technique. For the breast scans, fat suppression pulses were played out at the rate of one per 8, 16 or 24 TRs depending on k_r. For comparisons, a conventional centric ordered sequence with intermittent fat suppression (once per 16 TRs) was acquired with the same parameters. Temporal resolution was 50s for the conventional sequence and 12.5s for the TRICKS-ASSET sequence.

Results: Fig. 1 shows the simulations of time-signal enhancement curves using TRICKS-ASSET. The "true" enhancement curve is also plotted and there is very good agreement between the two suggesting that TRICKS can accurately provide quantitative information with high temporal resolution. Figure 2 shows profiles through the rim enhancing tumour using TRICKS and the true profile. Note that the ringing is minimal even for the small size of the tumour (3 mm radius). Figure 3 shows a typical image obtained using our sequence (right). The conventional fat suppressed centric acquisition image is shown for reference in Fig. 3 (left). The spatial resolution for both sequences was 0.8x1x3 mm; however the temporal resolution for our sequence (2b) was 12.5 s versus 50s for the conventional 3D FGRE (2a). Note that the quality of fat suppression is comparable.

Conclusion: We have demonstrated using simulations and data from patients, the feasibility of using TRICKS with parallel imaging for obtaining ultra high spatio-temporal resolution dynamic tumour images. The use of a novel EC compatible fat suppression will improve the visualization of small lesions as well as eliminate the need for data-subtraction, which can cause errors due to mis-registration from improper breath-holding in abdominal scans. A clinical study on patients with known tumours in the breast and liver is underway to validate this sequence clinically.

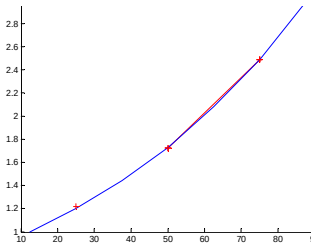

Figure 1. Signal enhancement curve for the 6 mm diameter tumour using TRICKS (crosses). The solid line is the true enhancement. Time axis is 10-90s.

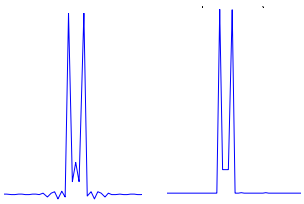

Figure 2. Profile through the rim enhancing tumour for TRICKS (left) compared to the true profile (right). Note the minimal ringing using TRICKS despite the small size (3 mm radius).

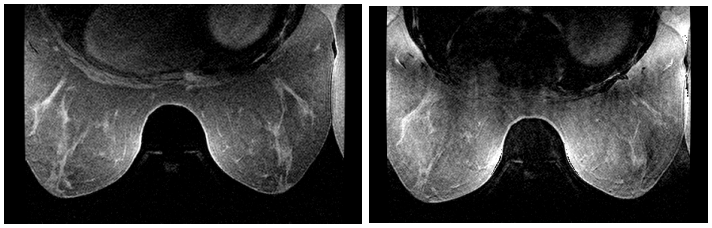

Figure 3. Comparison of conventionally acquired centric ordered (left) versus one phase of the EC tricks ASSET sequence with ESPECIAL (right). Temporal resolution was (50s left) versus 12.5s (right). Spatial resolution was 0.8 mm x 1mm x 3 mm for both

References:

1) Plewes et al. ISMRM 1993; 1251. 2) Liang et al. IEEE TMI 3) Korosec et al. 36: 345-351 (1996) 4) Kuhl et al. Radiology; 211:101-110 (1999)