Faster Quantitative Brain Imaging in Pediatric Patients by Using IR-TrueFISP

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Introduction: Deficits in neurocognitive function have been observed in survivors of pediatric acute lymphoblastic leukemia (ALL) as well as malignant brain tumors. These patients typically undergo aggressive treatment, i.e. cranial irradiation therapy and/or chemotherapy. Following treatment, analysis of brain morphology in these survivors demonstrated (a) evidence of white matter (WM) loss and/or failure to develop WM at an age appropriate rate [1], (b) a significant association between reduced volumes of normal appearing WM and intellectual, attentive and academic achievement [2], and (c) that WM volume losses are detected earlier than associated neurobehavioral changes [3]. Reliable non-invasive volumetric WM measures are therefore instrumental in assessing the efficacy of interventions designed to protect the normal brain and also for early identification of patients at high risk for substantial impairment. Quantitative MRI or T1, T2, PD, FLAIR mapping, has been successfully used to extract WM volumes [4]. However, these methods are time consuming and provide only a limited number of slices. Aim of this study was to assess in pediatric patients whether IR-TrueFISP [5], an inversion recovery prepared balanced SSFP sequence that has been recently introduced as technique to quantify tissue parameters from a single acquisition, can be used to accelerate the imaging process.

Methods: An IR-TrueFISP sequence was implemented on a 1.5T Siemens Magnetom Symphony scanner (Siemens Medical Solutions, Erlangen, Germany). Magnetization preparation was performed by applying an adiabatic inversion pulse and $\alpha/2$ SSFP preparation. The relaxation curve was sampled with a segmented TrueFISP experiment (TR/TE 5.4/2.7ms, α 50°, matrix 189×256, FOV 230mm, SL 4mm, TA 3:06min). Each segment consisted of 21 phase encoding steps equally distributed over the *k*-space. 50 segments were acquired during the recovery of the magnetization. 9 repetitions were necessary to fill k-space. Time between subsequent inversion pulses was 10 sec. 5 patients (2-21, median 14 years; 3 patients after ALL treatment and 2 with malignant brain tumor) underwent a clinical imaging protocol after informed consent had been obtained by the patient, parent or guardian, as appropriate. The exam included the following standard protocols for tissue quantification: (a) FLAIR (TR/TE/TI 9000/119/2470ms, TA 3:41min), (b) 4 sets of IR-TSE images at different TI times for T1 quantification (TR/TE/TI 2500/29/100, 500, 900, 2330ms, ETL 11, TA 1:32 min per image), and (c) a multi-echo SE sequence for T2 quantification (TR/TE/TE_{inter} 2000/22.5-360/22.5ms, ETL 16, TA 6:28 min). A 3-parameter fit to the IR-TrueFISP signal recovery curve yielded T1, T2, PD maps by utilizing the analytical equations described in [5]. Calculated T1- and T2 maps from IR-TrueFISP were compared to those obtained with conventional methods. A quantitative assessment of the correlation between the respective maps was performed by using scatter plots. For these comparisons only pixel from within the brain were considered; the skull was masked out.

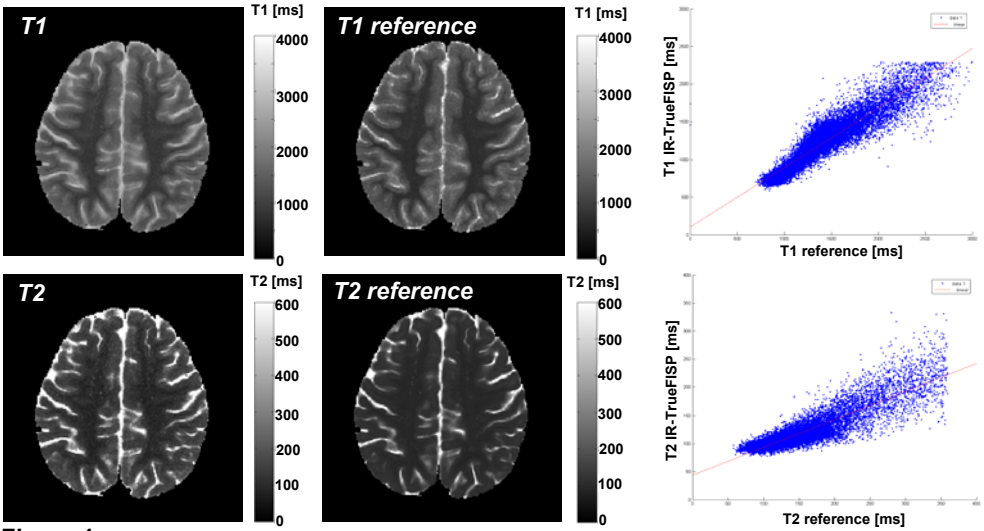

Figure 1

Results: Figure 1 shows calculated brain T1 and T2 maps of a 2-year old ALL survivor and respective T1 and T2 maps obtained from the same patient by using standard acquisition protocols and quantification algorithms. Scatter plots, where IR-TrueFISP-based T1 and T2 values were plotted vs. the corresponding conventional T1 and T2 values are also depicted. A linear curve fit for the T1 data yielded a slope of 0.79 and an intercept of 105. R^2 was 0.89. Fit parameters for the T2 plot were: slope 0.50, intercept 44 and R^2 0.92. In our complete cohort of patients, R^2 was between 0.78 and 0.93 ($p<0.001$).

Discussion: In this study we explored the use of IR-TrueFISP for quantitative brain analysis, which is of specific importance in monitoring WM changes in brain tumor and ALL survivors. For this purpose we compared conventional methods already established in our institution with IR-TrueFISP imaging. Our results show an excellent linear correlation between reference- and IR-TrueFISP-based relaxation times in all patients, whereas slope and intercept of the regression line deviate from the ideal values (1 and 0 respectively). Most likely this is attributed to the fact that the quantification algorithm is very sensitive to flip angle variations [6]. The model neither accounted for flip angle variations in slice direction nor for B_1 field inhomogeneities, which should be the scope of further investigations. Furthermore, IR-TrueFISP offers the possibility to derive synthetic images with various contrasts (e.g. FLAIR, T1w- and T2w TSE etc) once the tissue relaxation times have been determined by the mono exponential 3-parameter-fit. Our calculated PD maps and our synthetic TSE and FLAIR images derived from the IR-TrueFISP parameter maps resembled very well the contrast of equivalent imaging protocols. Hence, the number of necessary exams could be drastically reduced should this technique prevail. We achieved a 6-fold acquisition time reduction, eliminated the need for co-registration of relaxation maps, and thus conclude that our results strongly support the use of this new technique in pediatric brain applications.

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