

Investigation of the necessity of pre-contrast T1-determination in DCE MRI; simulations and clinical data

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Introduction: Dynamic contrast-enhanced (DCE) MRI is an established method to assess blood-brain barrier (BBB) integrity and brain hemodynamics. Standard tracer kinetic models are established for estimation of kinetic parameters. Quantification requires an accurate estimation of the CA induced change in T1 relaxation rate in tissue and blood which in turn require knowledge of baseline T₁ values (T_{1,0}). The need for T_{1,0}-data results in additional scan-time, and raises challenges related to image co-registration and additional image processing steps. The added value of using T_{1,0} maps in DCE analysis has thus been questioned (1). The purpose of this study was to compare K^{trans} values in primary brain tumors obtained using fixed T_{1,0}-values compared to using calculated pixel-wise T₁-values through simulations and clinical data. A secondary aim was to assess the variation in baseline T₁-values observed in brain tumors.

Subjects and Methods: A total of 64 examinations from 10 patients with gliomas were included in the study. All patients were imaged at multiple times during treatment as part of an ongoing prospective treatment monitoring study. T_{1,0}-maps were generated from a Look-Locker (LL) based inversion recovery sequence (2) and DCE data was obtained with a 3D saturation recovery (SR) based gradient echo sequence. The extended Tofts model (3) was applied for DCE analysis. The effect of varying T_{1,0}-values on the resulting K^{trans} estimates was simulated by estimating the variation in K^{trans} due to deviations in T_{1,0} from the nominal value. In the clinical data K^{trans} was estimated using the exam specific T_{1,0} (Method 1), using pixel-wise T_{1,0} values for each examination (Method 1), using the patient specific median T_{1,0} in tumor at first exam (Method 2) or a fixed value of 1204 ms, the median T_{1,0} in tumor from all patients (Method 3).

Results: A boxplot of the percent change in median T_{1,0} tumor values in all patients over time is shown in figure 1. Exam 6 is 4 months after the first exam. A gradual increase of T_{1,0} was observed across all patients during the course of the treatment and during the post treatment period.

Figure 2 shows the simulated error in K^{trans}-estimates when using T_{1,0}-values different from the true T_{1,0}. In typical K^{trans} values (0-0.15 min⁻¹) using a lower/higher T_{1,0} compared to the nominal value leads to over/under-estimation of K^{trans}, respectively.

Figure 3 A shows the distribution of tumor T₁ and the corresponding tumor K^{trans} histogram values using methods 1-3 in a sample patient. Figure 3 B shows the T₁ map and corresponding K^{trans} maps estimated from the three methods. An increase in tumor K^{trans} heterogeneity is shown in the histogram obtained from methods 2 and 3 compared to method 1.

Discussion/conclusion: There are three main findings from this study: First, median T_{1,0} in tumor increases significantly during the course of the treatment. Second: in spite of the increase in T_{1,0} over time, relative change in K^{trans} is estimated with good accuracy even when a constant T_{1,0} is assumed. This is due to the fact that the derived K^{trans} values are fairly insensitive to changes in T_{1,0} for high T_{1,0} as seen from the simulations in Fig 1 and the bias introduced by the increasing T_{1,0} is small relative to the overall temporal trend in K^{trans}. Third, using fixed T_{1,0} may result in an artificially broad distribution of tumor K^{trans} values. This effect is attributed to the rather heterogeneous distribution of T_{1,0} values present in gliomas which is not accounted for in the K^{trans} estimation when a fixed T_{1,0} is assumed. For a correct assessment of K^{trans} distributions throughout a tumor volume, using a calculated T_{1,0} map is thus recommended.

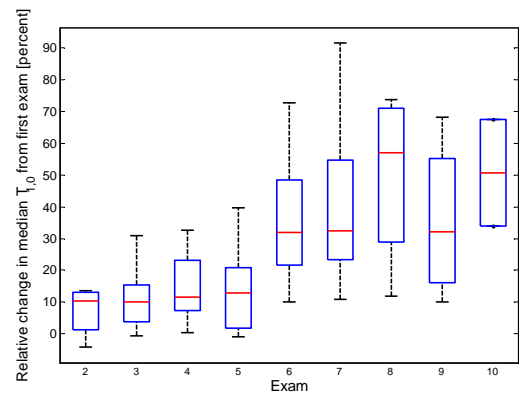


Figure 1: Relative change in median T_{1,0} from first exam (percent) The treatment period extended from exam 1 to 5

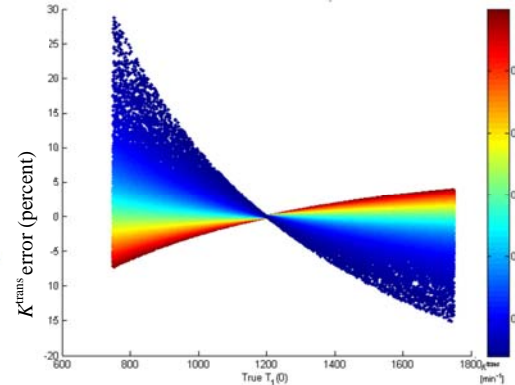
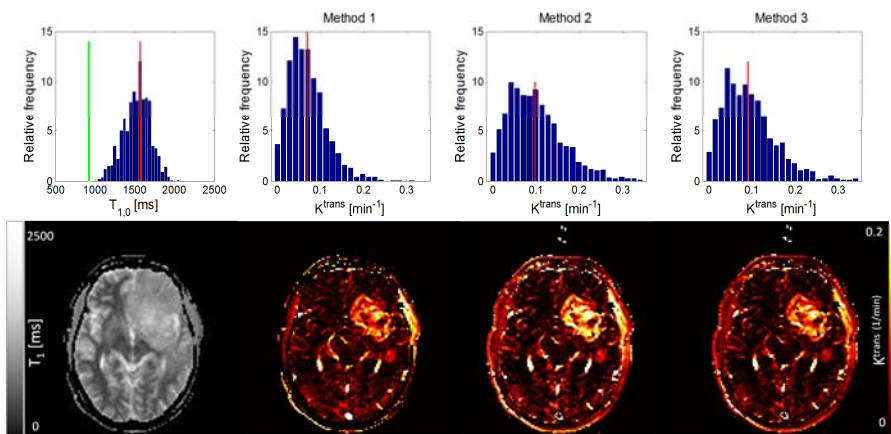


Figure 2: Error in K^{trans} as a function of assumed T_{1,0} for nominal T_{1,0} = 1200 ms



In glioma patients, an increase in tumor T₁ values should be expected during the course of the treatment and also in the post-treatment period. In spite of this increase in T₁, longitudinal changes in K^{trans} can be estimated with good accuracy assuming a fixed T_{1,0}-value. However, the heterogeneity in tumor K^{trans} values may be over-estimated when a fixed T_{1,0}-value is used since this approach does not account for the distribution of T₁-values present in the tumor volume.

Reference List

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