Impact of precontrast T1 relaxation times on DCE-MRI pharmacokinetic parameters: T1 mapping versus a fixed reference value

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Background: In order to calculate DCE-MRI pharmacokinetic Tofts[1] model-based parameters (K^{trans}, K_{ep}, V_e) and the semiquantitative initial area under the gadolinium curve (iAUGC), the measured signal intensity over time curve must be converted into a gadolinium concentration over time curve. This conversion requires knowledge of the T1 relaxation time of the tissue of interest (at pre-contrast) to correct for T1 relaxation time shortening induced by the presence of contrast material[2]. In practice, there are two methods implemented into commercially available DCE-MRI post-processing software: a) T1 relaxation time measurement by variable flip angle sequences or b) the implementation of a fixed reference value, mainly literature based. Method (a) allows for individual T1 relaxation time measurement per pixel whereas method (b) applies the same estimated T1 relaxation time to all pixels.

Purpose: 1) To measure the differences in DCE-MRI pharmacokinetic parameters (K^{trans}, K_{ep}, V_e, iAUGC) calculated using T1 relaxation time measurement vs. estimation methods (a versus b).
2) To assess the behavior of DCE-MRI pharmacokinetic parameter (K^{trans}, K_{ep}, V_e, iAUGC) output with changing T1 relaxation times.

Material and Methods: 15 female patients with uterine fibroids (mean age 44 years, range 28-60) were randomly selected from PACS and defined as the study group. All DCE-MRI studies were performed at 1.5T (Avanto, Siemens, Erlangen, Germany), using variable flip angle T1 mapping (flip angles: 2, 8, 20) and a 4D, time resolved MR angiography sequence with interleaved stochastic trajectories (TWIST) after the injection of 0.1 mmol/kg gadobenate dimeglumine (Bracco Diagnostics, Princeton, NJ). All DCE-MRI studies were processed on a dedicated DCE-MRI post-processing platform, Tissue4D™ (Siemens Healthcare, Erlangen, Germany) using Tofts modelling and calculation of pharmacokinetic parameters (K^{trans}, K_{ep}, V_e, iAUGC). To investigate purpose (1), all DCE-MRI studies were processed twice; first using T1 times calculated for each voxel from a set of variable flip angle sequences, and secondly using a fixed reference T1 relaxation time of 1000 milliseconds [ms]. To investigate purpose (2), a subset of 5 randomly selected DCE-MRI studies were processed using T1 relaxation times between 0-2000 entered in 100 ms steps. For both approaches, three regions of interest (ROI) were placed, one in each tissue: the uterine fibroid, the left psoas muscle and the fifth lumbar vertebra. The exact location of the ROIs was maintained for each new calculation of DCE-MRI pharmacokinetic parameters (K^{trans}, K_{ep}, V_e, iAUGC) after T1 relaxation times were changed (variable flip angle versus fixed reference value and stepwise increasing T1 relaxation times).

Table 1: mean percent difference of pharmacokinetic parameters using variable flip angle technique versus fixed reference value (1000 ms) for T1 relaxation time estimation.

structure	K^{trans}	K_{ep}	V_e	iAUGC
fibroid	41.2%	6.6%	36.6%	42.0%
psoas muscle	28.6%	10.4%	24.2%	31.1%
bone (L5)	52.3%	51.7%	49.6%	54.9%

Table 2: Mean, standard deviation (SD) and (min/max) of percent change in pharmacokinetic parameters for stepwise (100 ms) increasing T1 relaxation times (0-2000 ms.)

structure	K^{trans}	K_{ep}	V_e	iAUGC
fibroid	10.4 ± 6.7 % (0 – 42.6%)	4.1 ± 7.4% (0.1 – 51%)	11.0 ± 23.2% (0 – 40.2%)	12.8 ± 6.8% (0 – 43%)
psoas muscle	12.2 ± 8.2% (0 – 50%)	5.8 ± 5.9% (0 – 37.7%)	10.3 ± 6.5% (0 – 42.4%)	12.5 ± 7.5% (4.1 – 44.9%)
bone (L5)	12.2 ± 7.6% (4.4 – 43.5%)	2.8 ± 3.0% (0 – 11.5%)	11.7 ± 6.4% (4.3 – 43.7%)	13.1 ± 7.0% (5.7 – 43.4%)

Results: The percent differences between pharmacokinetic parameter values for the various tissues calculated with and without T1 mapping are summarized in Table 1; Figure 1 shows K^{trans} values for the left psoas muscle for each study calculated with and without T1 mapping. Table 2 summarizes the percent changes of pharmacokinetic parameters for stepwise increasing T1 relaxation times. The range of percent change of pharmacokinetic parameters between two calculations with T1 relaxation times 100 ms apart, was 0-50%. Figure 2A-C expresses the behavior of K^{trans} of the psoas muscle with stepwise increasing T1 times; the psoas muscle was deliberately chosen to show impact of changing T1 relaxation times on tissue with homogeneous perfusion. The curves further demonstrate that a 100 ms increase for initial T1 relaxation times <1000 ms, which represents most tissues of interest for DCE-MRI[3], results in a measurement error of >10%.

Conclusion: There is a considerable, potentially clinically significant difference (6.6 - 54.9%) between DCE-MRI pharmacokinetic parameters (K^{trans}, K_{ep}, V_e, iAUGC) calculated by using a pixel-based T1 relaxation time measurement vs. a fixed reference value. A distinct relation between fixed T1 relaxation times and resulting DCE-MRI pharmacokinetic parameters is found. Increasing T1 relaxation times yield lower pharmacokinetic parameter values within the same DCE-MRI data set, inversely this results in a higher measurement error for clinically relevant T1 relaxation times <1000ms, if different initial tissue T1 relaxation times are used. T1 mapping provides a more accurate estimate of T1 relaxation times than simple population-based estimation, because of the pixel-based measurement; a fixed reference value may have greater reproducibility. Clinical or research studies must use a standardized value if using a fixed reference for tissue T1 relaxation time in order to be comparable and to limit measurement error.

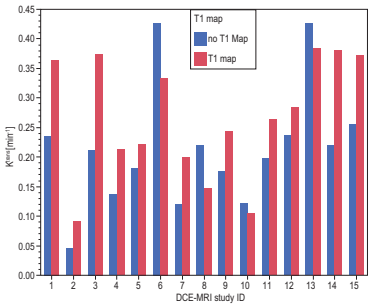

Figure 1: K^{trans} values of the left psoas muscle calculated with a T1 map (variable flip angle technique) and a fixed reference value of 1000ms.

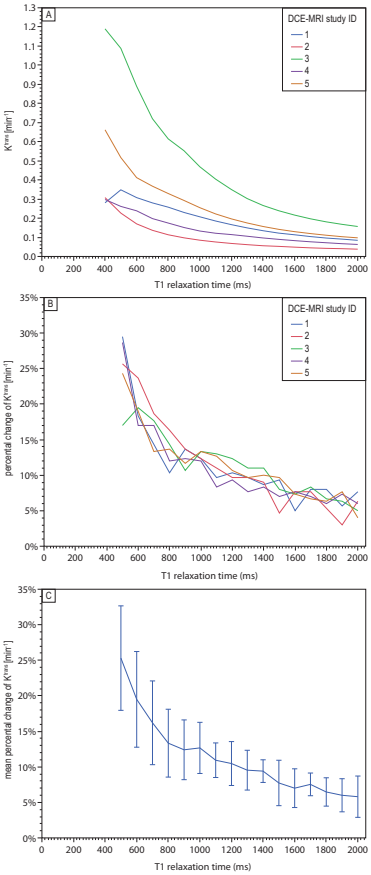

Figure 2: Behavior of K^{trans} values of the psoas muscle with increasing T1 relaxation times (x-axis). y-axis: A) K^{trans} of 5 DCE-MRI studies; B) percent change of K^{trans} in 5 DCE-MRI studies; C) mean percent change ± standard deviation of K^{trans} in 5 DCE-MRI studies.

References:

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