Mono-exponential $T_2$-analysis of a two-pool system – Does echo-spacing matter?
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Target audience
The presented work will be beneficial to anyone using the spin-echo $T_2$ quantification approach.

Purpose
It is generally well accepted that tissue exists of multiple relaxation components, such as for example the free water protons and myelin-bound water protons in brain tissue$^1$. However, the spin-echo based quantification of a single $T_2$ on such tissues is commonly considered to be the gold standard. Therefore, we have investigated whether the echo-spacing ($\Delta T_E$) matters when performing a mono-exponential analysis of a two-pool system.

Methods
We have performed Bloch simulations for a spin-echo sequence of a two-pool system. Pool fractions were varied from 10% to 90% with $T_{2,1} = 50$ms and $T_{2,2} = T_{2,1}/10$ (5ms). The relaxation curve was sampled every ms up to $3T_{2,1}$ (150ms), Gaussian noise was added with an SNR ~50 for the initial signal at $T_E = 0$, creating 100 measurements per $T_E$ (simulating an average ROI size). Subsets were taken with constant echo-spacing ($\Delta T_E$) ranging from 1ms up to 30ms. The subsets were mono-exponentially fitted, omitting sample points where $S < 3x$ standard deviation of the added noise.

Results
Figure 1 $T_2$ as a function of the echo-spacing, without noise (left), mean values after analysis of signal with noise addition (middle) and a zoomed in view of this graph with additional error bars indicating the standard deviation for $T_{2,2}$-pool size of 10%, 20% and 30% (right).

The shorter the echo-spacing, the larger the influence of the fast relaxing pool, the larger the fast-relaxing pool the larger its influence on the obtained $T_2$ (Figure 1). Noise influences the observation of $T_2$ (Figure 1) and might lead to a reduced number of sample points to fit as a result of a fast decay due to a large $T_{2,2}$-pool. Figure 2 shows box-plots of the simulations with 10%, 20% and 30% $T_{2,2}$-pool fractions, comparing 5, 8, 10, 12 and 15ms echo-spacing. The largest difference between the mean as well as median observed $T_2$-values is obtained in a sample with 30% $T_{2,2}$-pool size and is approximately 3ms ($\Delta T_E = 5$ms versus $\Delta T_E = 15$ms).

Discussion
Simulation results illustrate the independency of the $T_2$-quantification on $\Delta T_E$ and pool fraction (fraction ≤30%) in a no-noise situation as well as the situation with noise (Figure 1). The observed differences between the means and medians (best visible in Figure 2) does not exceed 3ms when $T_{2,2}$-pool fractions ≤ 30% and 5ms ≤ $\Delta T_E$ ≤ 15ms. In practice, this difference will not be considered to be an observation of different $T_2$, since the typical standard deviation obtained in an ROI of in vivo white matter is 6ms for a 10ms spaced $T_2$-quantification (single-echo spin-echo with TR = 2.5s; 30 echoes, $T_E_{\text{max}} = 300$ms; voxelsize 1.3x1.3x4mm$^3$).

Conclusion
We have shown that the echo-spacing in a spin-echo acquisition for $T_2$-quantification does not matter when performing a mono-exponential analysis of a two-pool system.

References