Evaluation of Vascular Transfer Constants using Dynamic T1-Mapping during Contrast Agent Administration

Uwe Klose[1], Sotirios Bisdas[1], Herbert Köstler[2], and Johannes Tran-Gia[2]
[1]*Department of Diagnostic and Interventional Neuroradiology, University Hospital of Tübingen, Tübingen, Germany,* [2]*Institute of Radiology, University of Würzburg, Würzburg, Germany*

Target audience Neuroradiologists, Neuroscientists, Physicists

Purpose

A new fast T1 mapping method allows the direct observation of T1 changes during contrast-agent (CA)-enhanced dynamic measurements, (DCE)). We sought to examine the quality of the resulting Patlak-plots and the plausability of the calculated vascular transfer constant(K^{trans}) values.

Methods

All measurements were performed with a conventional 3T MR whole-body scanner (Trio Siemens) equipped with a 32-channel head coil. A new sequence for fast T1 mapping [1] was installed, consisting of an inversion pulse and the acquisition of 1000 single radial trajectories within a timeof 6 s, each having a different inversion time. In an iterative evaluation process [1], T1-values can be calculated pixelwise. A further iterative method was applied to correct for errors due to incomplete relaxation between successive measurements [2]. 33 subsequent shots of the described sequence were acquired with an intra-shot time delay of 3s (FOV = 230×230mm², slice thickness = 3mm, TE = 2.5ms, measurement time 6.0ms, α = 7°). This sequence was applied in a patient with primary brain lymphoma during CA administration (Gadovist®, Bayer Schering Pharma AG).

We used the values in the unenhanced T1-map to calculate the reference values for the relaxation rate $R_{1,ref}$. $\Delta R1(t)$ values in selected ROIs were assumed to be proportional to the concentration of CA in tissue ($C_t(t)$) and in plasma ($C_p(t)$). For the time course of $C_t(t)$, the following model was used:

$$C_t(t) = K^{trans} \int_0^t e^{-k_{ep}(t-\tau)}\, C_p(\tau)d\tau + v_p C_p(t) \quad (1)$$

with K^{trans}: transfer rate constant of the CA from plasma into the interstitial space, k_{ep}: transfer rate from the interstitial compartment to the vascular compartment, v_p: fractional volume of the CAs vascular distribution space [3-5]. The K^{trans} constant is the slope in the Patlak plot with $C_t(t)/C_p(t)$ being the ordinate and $\int_0^t e^{-k_{ep}(t-\tau)}\, C_p(\tau)d\tau \; \frac{1}{C_p(t)}$ the abcissa. This abscissa expression is called „stretch time". The Patlak plot does not depend on the proportional factor between C(t) and $\Delta R1(t)$, therefore C(t) = $\Delta R1(t)$.

Results

The calculated T1-maps of the first and the last measurement of the dynamic examination are shown in Fig.1. The T1 reduction in the tumor region due to the CA accumulation can be clearly seen. Regions of interets (ROIs) were drawn in tumor tissue, in normal white matter and in the superior sagittal sinus, which was used to estimate the plasma concentration $C_p(t)$ since no arterial input function was feasible at the examined slice. The obtained time courses for T1 and $\Delta R1(t)$ are shown in Fig. 2., the resulting Patlak plots in Fig.3. The chosen k_{ep} values reflected the minimal residuals between regression line and data points. The results were 0.0, 0.04, 0.18, 0.18 1/min for k_{ep} and 0,002, 0.0025, 0.066, 0.095 1/min for K^{trans} in the blue, red, cyan and green region, respectively (Fig. 1-3).

Discussion

T1-mapping during the CA administration overcomes the estimation of T1-values from the signal intensity time curves as well as the need for T1-mapping prior to the dynamic series. This procedure may eliminate possible errors, (i.e. due to patient movement between the measurements). The obtained results in this study are in good consistence with the published models [3-5], as shown by the remarkably low residuals between data points and fitted line (Fig.3).

Conclusion

Estimation of K^{trans} in DCE studies can be satisfactorily performedby using the presented dynamic T1-mapping during the CA administration.

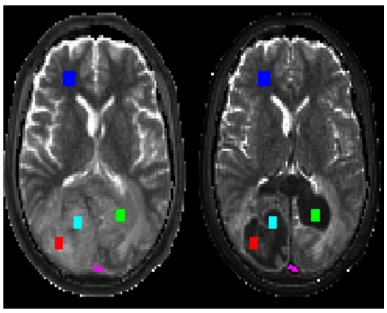

Fig. 1: T1-maps of the first and last measurements with selected ROIs: tumor regions (red, green, cyan), white matter (blue) vein (magenta).

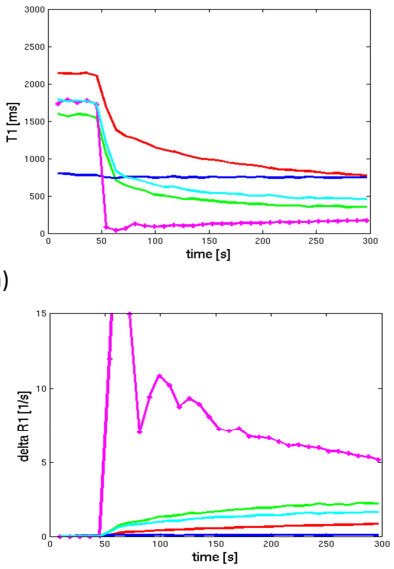

Fig. 2: Mean T1-values (a) and mean ΔR1-values (b) in the selected ROIs during the dynamic measurement .

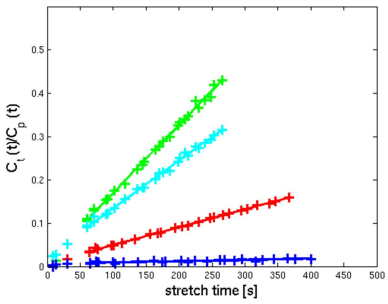

Fig. 3:Extended Patlak plot with points for each single meaurements (+) and regression lines for the selected ROIs. The slopes of the lines are the K^{trans} values. .

References

1. Tran-Gia J et al., Proc ISMRM 2013;21, 2454,
2. Siversson C et al., J Magn Reson 2009;30, 834-841
3. Patlak C et al, J Cereb Blood Flow metab 1983;5,584-590
4. Tofts PS et al, J Magn Reson Imaging 1999; 10, 223 – 232
5. Bagher-Ebadian H, Magn Reson Med 2012; 68, 241 - 251