# Dynamic Susceptibility Contrast Imaging using a multi-echo spiral sequence

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## Introduction

To characterize microvasculature, one can perform a DCE-MRI experiment (a first injection of contrast agent (CA) to estimate the vessel wall permeability) followed by a DSC-MRI experiment (a second injection of CA to estimate relative blood volume (rCBV), relative blood flow, etc.) [1]. The DSC experiment can even yield information on vessel size if a gradient echo and a spin echo are simultaneously acquired [2]. However, estimates from a DSC experiment performed after a DCE-MRI experiment (two injections of CA) may differ from the estimates derived from a single DSC experiment (one injection of CA), especially due to different $T_1$ effects [3]. Low flip angle have been proposed to reduce these effects but this approach is not compatible with the acquisition of vessel size estimates which requires a spin echo. In this study, we investigate how $T_1$ effects contribute to rCBV estimates in the case of one and two consecutive injections of CA. To achieve this goal, we used a mutli-echo spiral sequence – which allows short echo-times – in a rat glioma model.

## Materiel and method

Experiments were performed at 4.7T (Bruker Avance III system) using volume/surface cross coil configuration. Wistar rats (n=5), bearing an intracerebral C6 glioma (18 days of growth) were anaesthetized using isoflurane (2%) and their tail vein was equipped with a catheter for the 2 CA injections.

MRI protocol: T2w imaging for anatomy, gradient multi-echo spiral out sequence (FOV=3x3cm$^2$, matrix=128x128, 1mm thick single slice, $T_R$=500ms, 2 interleaves, bandwidth 625kHz, $T_E$=[0.95, 13.8, 26.6, 39.4, 52.2ms], 1 image/s) to monitor the 1st passage of Gd-Bolus (Gd-DOTA, 200µmol/kg), 3 minutes later, same sequence to monitor the 1st passage of a second Gd injection (same concentration). Special attention was paid to the refocusing between two gradient echoes: an appropriate trim gradient lobe was derived from a previous trajectory measurement so that the shift between theoretical and effective trajectories caused by eddy currents and hardware imperfections is compensated for each echo [4]. $T_2$* maps obtained with this approach matched those obtained with a classical multi-gradient echo imaging technique. Image reconstruction was performed within Matlab environment and using home-made software.

$R_2$* changes over time ($\Delta R_2$*) were assessed using 2 methods:

Method 1) Using classical approach, $\Delta R_2$* was calculated pixel-wise from a single echo (3rd $T_E$ = 26.5ms) for each scan as: $\Delta R_2^* = -\frac{1}{T_E}\ln\left(\frac{S(t)}{S_{baseline}}\right)$. $S_{baselinee}$ was computed as the mean signal from the 10 first points.

Method 2) Using multi echoes approach, $\Delta R_2$* was calculated from the $T_2$* obtained using a non-linear fit algorithm and a two-parameter exponential decay: $\Delta R_2^* = \frac{1}{T_2^*(t)} - \frac{1}{T_2^*_{baseline}}$ with $T_2$*(t) computed by fitting $S(t) = S_0.\exp(-t_i / T_2^*)$ with $t_i \in \{T_E\}$.

Then, for both methods, $\Delta R_2$* curves were fitted pixel-wise by a gamma-variate function using a non-linear algorithm and rCBV were computed. rCBV estimates obtained for each injection and each method are compared. Every voxel returning a fit error was excluded.

## Results

Representative rCBV maps obtained with the 2 methods are presented in Fig.1 Comparisons between rCBV estimates derived from injection 1 and 2 and between method 1 and 2 are shown in Fig.2 for tumor and controlateral regions. Both figures underline the benefit of the spiral multi echo approach compared to the one based on a single echo. First, there are less rejected pixels. Moreover, correlation coefficients between rCBV estimates from injection 1 and 2 are clearly better for the second method, suggesting more robust results. Indeed, method 2 removes $T_1$ contribution from the MR signal. Thus, plotting $S_0$ provides information on the $T_1$ changes during CA passage (Fig.3). We observe that the 2 injections are not equivalent. $T_1$ effects at bolus peak are lower for injection 2 than for injection 1 but not abolished ($S_0$ increase for injection 1: +3.7%±0.4%, injection 2: +3.2%±0.8%). After bolus peak, $T_1$ effects decrease for injection 2 but not for injection 1. This is also detectable on Fig 3b. In tumor the $T_1$ effect at peak was lower due to reduced blood flow but the $T_1$ effect after bolus peak remains the same.

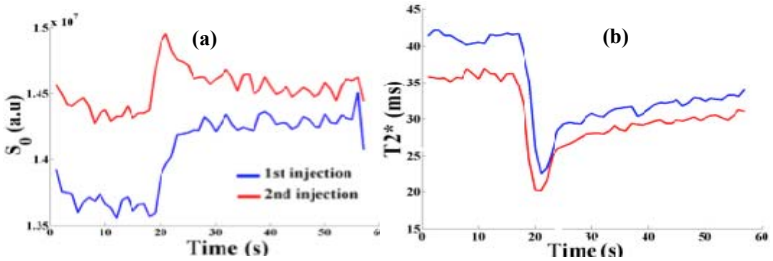


**Fig 3.** Plot estimates changes for both injections in controlateral region. (**a**) $S_0$ estimates. (**b**). $T_2$* estimates over time.

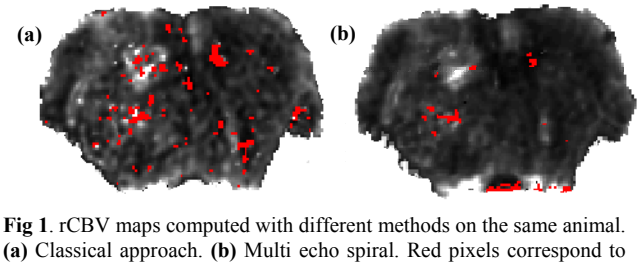


**Fig 1**. rCBV maps computed with different methods on the same animal. **(a)** Classical approach. **(b)** Multi echo spiral. Red pixels correspond to data that could not be processed (fitting error etc.).

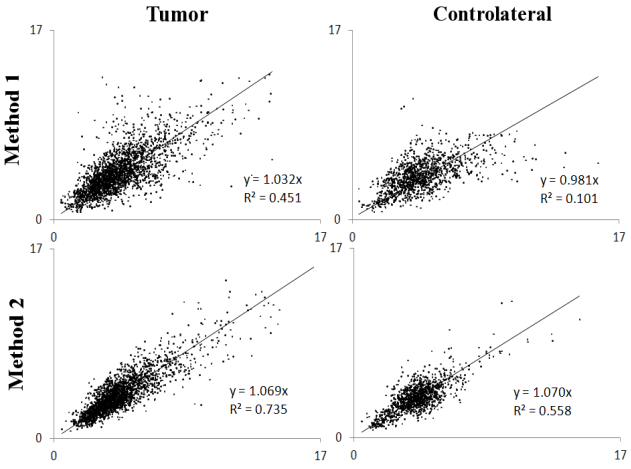


**Fig 2**. rCBV values (arbitrary units) derived from the data acquired during 1st injection (x-axis) vs. 2nd injection (y-axis) with the 2 methods in 2 different ROI.

## Discussion

This study shows promising results in investigating 1st passage bolus with multi-echo spiral imaging. First, $\Delta R_2$* estimates seem more robust. Secondly, the results suggest that DSC-MRI performed during a second injection of CA is less sensitive to $T_1$ effects (at bolus peak and during the return to baseline) than DSC-MRI performed during a first injection.

**References:** [1] T. Batchelor et al. *Cancer Cell*, 11(1):83–95, Jan 2007 [2] V.G. Kiselev et al. *J Magn Reson Imaging*, 22(6):693–696, Dec 2005 [3] Paulson EK et al. , 249(2):601-13, Nov 2008 [4] N. Pannetier et al. *ESMRMB Proceedings,* 2009.