Mapping blood volume fraction and vessel size index at steady-state: Impact of contrast agent dose and spin-echo time

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Introduction: Assessment of microvascular characteristics is of interest for the study of numerous pathologies such a cancer or stroke. Cerebral blood volume fraction (BVf) and vessel size index (VSI) can be mapped with a MRI steady-state approach: one measures the reduction in T2 and T2* induced by the injection of a contrast agent (CA) (1, 2). Optimizing the amount of dose injected is highly desirable to minimize side effects, cost, and to ease the transfer in the clinic. To maintain the sensitivity when reducing the amount of injected CA, one can increase the echo-time, at the expense of signal to noise ratio (SNR). The goal of this study was to optimize the steady-state protocol to map BVf and VSI in healthy rat brain (n=5) by characterizing the impact of three different doses of CA and three different spin-echo times.

Material and methods: ***MR acquisitions:*** Imaging was carried out on a 4.7T system (Bruker Avance III). The following imaging protocol was performed on 6 healthy anesthetized Wistar rats (2% isoflurane in Air+20% O_2): **i**) T2w (anatomical imaging), **ii**) three Multi Gradient Echo Spin Echo (TR=4000ms, 40 echoes; FOV=30x30mm; voxel size =234x234x800µm^3, 5 slices, NA=1) with different spin-echo times (TSE = 60, 75 or 90ms), **iii**) intravenous injection of ultrasmall superparamagnetic iron oxide particles (P904, 66µmol Fe/kg, Guerbet, France), and **iv**) three Multi Gradient Echo Spin Echo with different spin-echo times (TESE = 60, 75 or 90ms) (same as step ii). Steps iii and iv were repeated 3 times to monitor the impact of increasing the dose of P904 on BVf and VSI imaging. In the following, the first dose of CA (66µmol of Fe/kg) is denoted 1d, the second dose 2d (2 injections of 66µmol of Fe/kg) and the third dose 3d (3 injections of 66µmol of Fe/kg). ***Data analysis:*** Two ROI were drawn, one on the brain and one on the image background to estimate the noise. The signal to noise ratio (SNR) was then estimated from each echo time before and after contrast agent. The contrast to noise (CNR) was eventually obtained for each echo time by subtracting the SNR obtained after CA injection from that obtained before CA injection.

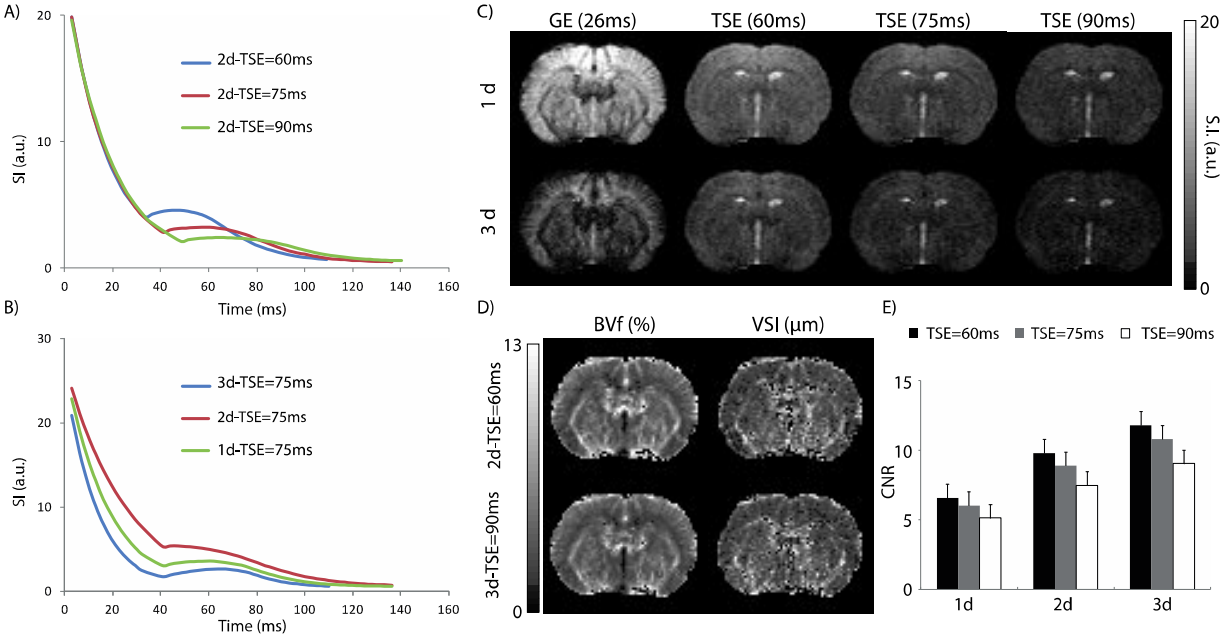

Figure 1A shows the signals collected in the ROI brain using a constant CA (2d) and using three different spin-echo times (TSE=60, 75 and 90ms) whereas the Fig.1B illustrate the impact of the dose (1d, 2, and 3d) using a TSE constant (75ms). One can clearly observe different temporal evolutions of the MR signal. In Fig. 1C, gradient and spin echo weighted images collected in one rat for two different CA doses are displayed. Both CA and echo-time impact the SNR. Corresponding BVf and VSI maps obtained with two different doses and two different spin-echo times (Fig. 1D) show the same patterns and visually the same SNR. The CNR for each dose and each echo time is represented in Fig. 1E at the different spin-echo times. The short spin-echo time always yields the highest CNR. The CA dose 3d yields the highest CNR and we notice a smaller gain going from dose 2d to 3d (17%) than going from dose 1d to 2d (33%). The dose 2d at TSE=60ms yields a better CNR than dose 3d at TSE=90ms and results are comparable to dose 3d at TSE=75ms (paired t-tests). For BVf, CNR evaluated at the gradient-echoes acquired during the free induction decay were found similar for all CA doses and spin-echo times.

Conclusions: When mapping BVf and VSI at 4.7T, the use of an echo time beyond 60ms decreases the CNR. Regarding the CA dose, no significant changes has been observed on BVf map whereas the use of 200µmol of Fe/kg yields the best CNR at the Spin-echo time but two-third of the dose appears almost equivalent in term of CNR.

References: (1) Tropres *et al.* MRM 2001. (2) Lemasson *et al.* MRM 2013.