Dynamic Arterial Spin Labeling Functional MRI (DASL-fMRI)

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INTRODUCTION

Functional MRI techniques use the BOLD contrast as a robust marker of localized cerebral activity. However, the BOLD contrast is not quantitative, because it depends not only on changes in cerebral blood flow (CBF), volume (CBV), and blood oxygenation, in addition to a number of other parameters and constants of difficult estimation and calibration [1]. Amongst the hemodynamic physiological variables, CBF constitutes the best and most quantitative marker of the increases of cerebral activity. CBF can be quantified by arterial spin labeling (ASL), a technique that uses endogenous arterial water as a perfusion tracer [2, 3]. The models of quantification of CBF with ASL rely on measuring three basic parameters: the longitudinal relaxation time T_1 of the tissue, the time of transit τ of the arterial spins, and the difference of longitudinal magnetization between the control and the labeling steady-states. These three quantities can be dynamically and simultaneously measured using dynamic ASL (DASL) [4]. In the present work, DASL was applied to measure the functional CBF response to somatosensory stimulation in α-chloralose anesthetized rats.

MATERIALS AND METHODS

Sprague-Dawley (SD) rats weighing 250-350g were scanned in a Bruker system of 7T (Bruker-Biospin, Billerica, ME) equipped with gradients capable of 450mT/m (Resonance Research Inc., Billerica, ME). A home-built, transmit-only birdcage volume RF coil, 12 cm internal diameter, and a receive-only surface coil were used for all image acquisition. A small figure-8 shaped dedicated labeling RF coil [5] was placed underneath the neck of the animal, approximately 2cm away from isocenter. To prevent magnetization transfer, interactions between the different RF coils was minimized with the use of active decoupling circuits [4]. Dynamic ASL was obtained over a 2 mm-thick coronal slice that included the forelimb area of primary somatosensory cortex. Images were acquired using a GE-EPI sequence with the following parameters: TR/TE=250/25ms, FOV=25.6x25.6mm^2, matrix=128x128. A DASL frequency of 0.05Hz was used for determination of CBF, transit time τ and T_{1sat} at rest. For the functional experiments, a DASL frequency of 0.017Hz was used and the functional paradigm was defined so that stimulations were presented during the stationary period of the DASL cycles.

RESULTS

Fig. 1 shows a typical DASL time-course, which is used to obtain the three parameters: resting CBF, T_{1sat} and τ [4]. Fig. 2 shows the corresponding maps for each one of these parameters from a representative animal. In this case, the average whole-brain CBF value was 149ml/100g/min (Fig. 2a). T_{1sat}, which includes contributions from CBF as well as from magnetization transfer between protons in tissue water and macromolecules [4], had a mean value of 1200ms (Fig 2b). The transit-time map, shown in Fig. 2c, had an average value of 258ms. Fig. 3 shows the combined DASL-fMRI time-course. The functional hemodynamic response can be easily noticed on top of the DASL experiment. The control phase of the DASL cycle displays a robust BOLD response, while the labeling phase shows the functional mixing of BOLD and CBF contrast in anti-phase to each other. The inset shows the t-score functional map.

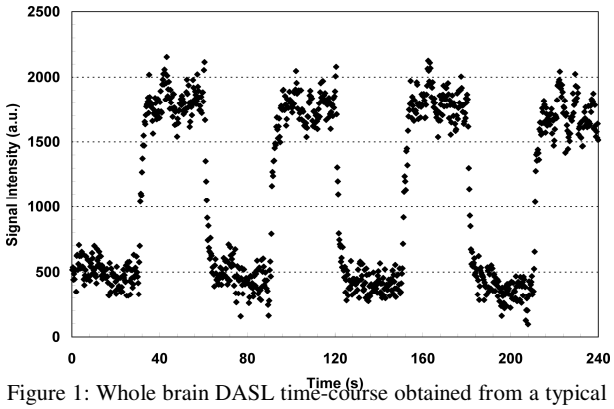

Figure 1: Whole brain DASL time-course obtained from a typical rat corresponding to the dynamic alternation of control and labeling phases of ASL.

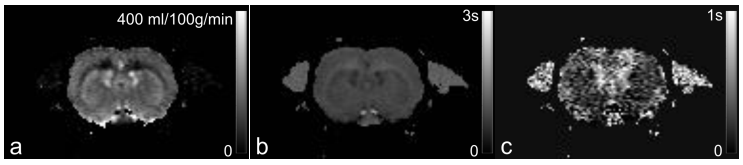

Figure 2: (a) Resting CBF map, (b) T_{1sat} map and (c) transit time map obtained from a single DASL acquisition.

DISCUSSION AND CONCLUSIONS

In this study, the combination of DASL with fMRI experiments shows the advantages of obtaining, in a single experiment, dynamic quantification of the resting and functional CBF, the transit-time τ and T1. DASL is an efficient way to probe these parameters dynamically, and is likely to constitute a versatile experimental platform for studying the spatial and temporal characteristics of functional cerebral hemodynamics. Further optimization of the technique will allow analysis of the vascular nature of the BOLD and the CBF responses, as well as the changes in vascular transit-times and perfusion territories associated with functional hyperemia.

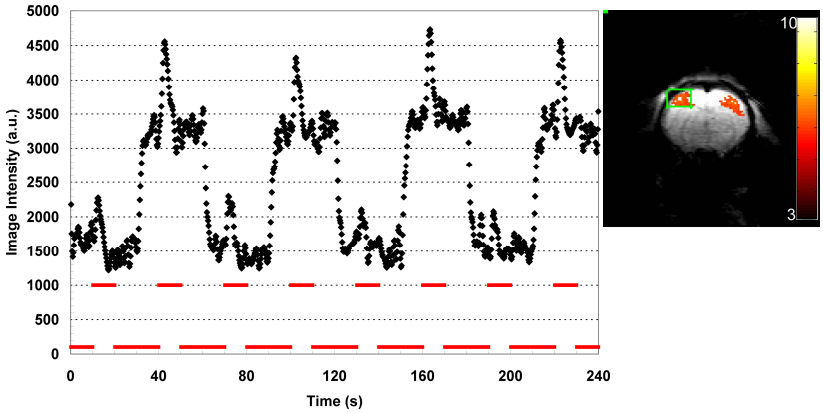

Figure 3: DASL time-course showing the BOLD response superimposed on the DASL evolution. Notice the higher response in the control (BOLD effect) compared to the response in the labeling phase (BOLD and CBF in anti-phase). The functional paradigm is shown in red. The inset shows the t-score functional map.

REFERENCES

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