Feasibility of Quantification of Cerebral Blood Perfusion using Multi-phase Inter-slice Perfusion Imaging

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Introduction : Arterial spin labeling (ASL) methods have been introduced to estimate blood perfusion without contrast agent. Using dynamic images based on ASL with multiple time intervals, blood perfusion could be quantified [1]. Dynamic ASL is commonly performed by Look-Locker sampling strategy based on echo planar imaging (EPI). However, EPI is weak in susceptibility effect and show unsatisfactory signal to noise ratio (SNR). Recently, a new technique using multiphase balanced steady state precession (bSSFP) readout sequence has been proposed [2]. Perturbations in magnetization for rapidly-flowing arterial blood are relatively small in bSSFP, which leads to quantification of arterial blood volume [2]. In this study, we performed a new perfusion-weighting technique, alternate ascending/descending directional navigation (ALADDIN) [3], with a multiphase-bSSFP sequence. The multiphase imaging acquisition can show dynamic change of perfusion signal, and thus the multi-phase ALADDIN may enable us to estimate cerebral blood volume (CBV) and cerebral blood perfusion (CBF) mainly in arteries.

Materials and Method

All experiments were performed on a 3T whole-body scanner (Siemens Medical Solutions, Erlangen, Germany) with a 12-element head matrix coil. One healthy volunteer participated in this study. To get perfusion images, 2D bSSFP images were acquired with ascending and descending orders. Alternating slice-select gradients (positive/negative) was also used to compensate for magnetic transfer effect. K-space was covered in three segments, and total 10 phase images between the time interval (TI) of 133-1328 ms with a step size of 133ms were carried out. Default imaging parameters to get a set of 2D bSSFP images were: TR / TE = 4.15 / 2.08 ms, flip angle = 40°, bandwidth = 592 Hz/pixel, matrix size = 128 x 96, FOV = 220 x 220 mm2, number of slice = 14, number of measurement = 48, slice thickness = 8 mm, and gap = 150%.

Tissue region of interests (ROIs) were defined manually at five different sites of gray matters (1 frontal lobe, 3 parietal lobe, 1 occipital lobe). A general kinetic model has been accepted to describe continuous ASL perfusion data [1]. Simulations based on the general kinetic model were performed with typical values: CBF= 50 mL/100g/min, $T_{1,eff}$= 1.6s, $T_{1,a}$ = 1.9s, $M_{0,a}$ = 1, arterial transit time (ATT)= 400 ms, λ= 0.9, τ=4s, and α= 1.0. The process of fitting the general kinetic models (estimating CBF, ATT, $T_{1,eff}$) to acquired perfusion data was performed using a nonlinear least-squares algorithm in the Matlab environment (The Mathworks, Natick, MA). Using model fitting, the effective impulse response function (IRF) assumed to be monoexponential with an effective relaxation time ($T_{1,eff}$) was acquired. Estimated CBF and the area under the IRF were used to determine CBV.

Results and Discussion The multiphase-bSSFP imaging using the proposed sampling scheme allowed to acquire dynamic perfusion images (Fig. 1) and demonstrated the feasibility of the quantification of CBF and CBV. Simulations using default parameters predicted that the perfusion images from ALADDIN could not show perfusion information in the early stage of perfusion, because of its continuous tagging scheme (Fig. 2a). Typical multiphase perfusion signals and the corresponding fitted curves obtained using the general kinetic model showed curve patterns similar to the simulation results (Fig. 2b). For five ROIs, the averaged estimated values (CBF, ATT, $T_{1,eff}$) and calculated CBV were displayed in Table 1. The estimated CBF values were similar with those of previous study [1]. According to a recently study [2], bSSFP readouts disturb labeled spins in tissue but preserve magnetization of rapidly-flowing arterial blood, providing the arterial blood volume. Based on this notion, it is possible that the source of blood volume signals in our study may mainly be originate from arterial blood volume, but further examination should be performed to demonstrate the exact signal sources.

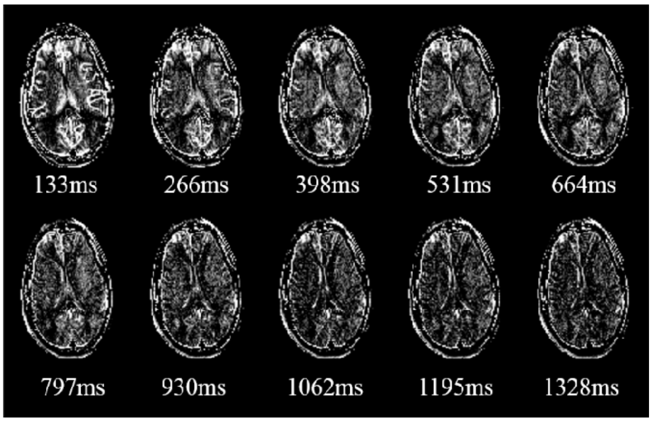

Fig 1. Balanced SSFP images with ALADDIN ordering scheme acquired with 10 TI, with a representative dataset.

	ATT (s)	CBF (ml/100g/min)	$T_{1,eff}$ (s)	CBV (ml/100ml tissue)
ROI1	0.27	55.1	0.91	0.84
ROI2	0.07	47.2	1.31	1.03
ROI3	0.07	49.7	1.41	1.17
ROI4	0.51	38.8	1.37	0.89
ROI5	0.07	49.2	1.20	0.98

Table 1. The mean estimated values using the general kinetic model for CBF, ATT, $T_{1,eff}$, and calculated CBV.

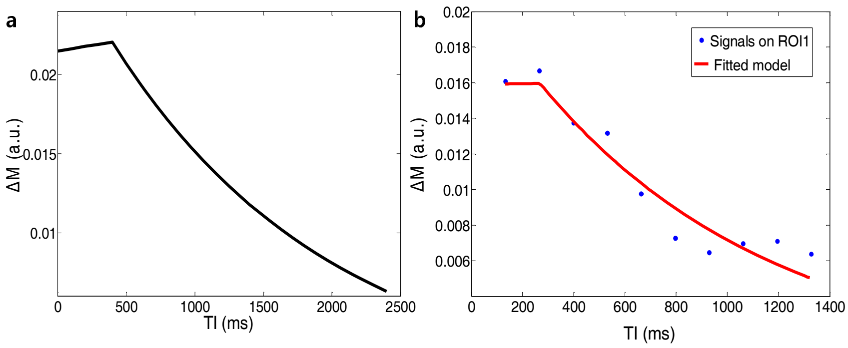

Fig 2. Simulated dynamic time course of multiphase bSSFP with ALADDIN data sets **(a)**; representative mean perfusion signals and the corresponding fitted curve **(b).**

References

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