An optimised dual-loop labeling coil for whole-brain perfusion studies

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Introduction

Continuous arterial spin labeling (CASL) using a separate labeling coil [1] is an attractive perfusion MRI technique particularly at high fields. Advantages include reduced RF power deposition and potential whole brain coverage without any magnetization transfer effects. Prerequisite is adequate labeling efficiency for all brain-feeding arteries. The aim of this project was to find a robust design of a labeling coil that achieves maximum inversion efficiency with high intersubject stability for generating perfusion contrast in the whole brain without exceeding SAR limits.

Method

As the efficiency of CASL crucially depends on the strength of the labeling field (B1), computer simulations of the B1 field and the specific absorption rate (SAR) in the human neck were performed using a dual-loop labeling coil consisting of a perpendicular pair of circular surface coils driven by a 180 ° phase-shifted RF, cf. Fig 1a. All calculations were done with HFSS (Ansoft, Pittsburgh, PA) solving Maxwell's equations with given boundary conditions in the frequency domain by employing the finite element method and adaptive meshing. The simulation included the fully parameterised labeling coil design with variable diameter of both surface coils and a variable thickness of the insulation (polypropylene) to a homogenous cylindrical phantom with dielectric properties of human tissue. For comparison, the B1 field distribution was obtained experimentally by the double-angle approach [2]. The coupling between the imaging coil (a helmet resonator with minimised stray field, cf. Ref. [3]) and the labeling coil was considered by both simulations and phantom experiments. In-vivo perfusion experiments were performed at 3 T with a gradient echo EPI sequence (TR = 6 s, TE = 22 ms, BW = 150 kHz). The labeling period and the post-labeling delay were 3.5 s and 1.5 s, respectively.

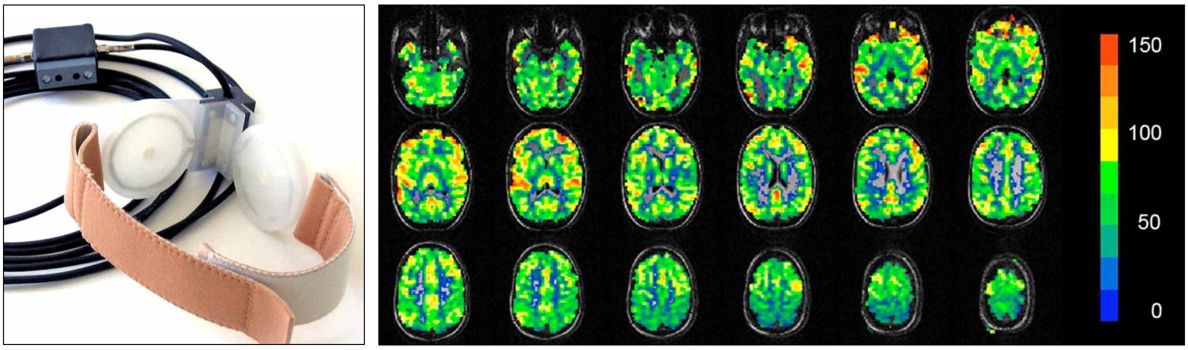

Fig. 1. (a) Design of the dual-loop labeling coil for in-vivo perfusion studies. (b) A whole-brain perfusion map obtained by CASL. The colors correspond to CBF values in ml/min/100g.

Results & Discussion

The final design of the labelling coil was optimised under three conditions: The maximum available labeling power (1.5 W), the maximum local SAR (8 W kg^{-1}) and a sufficiently high B1 field at the location of the brain-feeding arteries. Critical coupling between the imaging coil and the labeling coil further needs to be excluded in case of non-actively detuned coils. The choice of a 6-cm circular surface coils as applied in previous studies [4] could be approved under all of the above aspects, especially for a thickness of the insulation between the surface coil and the skin of 7-mm. For this value, the simulation of the SAR distribution yielded a maximum local SAR value of 4 W kg^{-1}. The optimised dual-loop labeling coil was found to produce B1 fields of about 4 μT and 2 μT at the assumed locations of the carotid artery (2 cm below the skin) and the vertebral artery (4 cm below the skin). With respect to previous numerical simulations [5], and for an average blood velocity of 20 cm s^{-1} and a labeling gradient of 2 mT m^{-1}, these values will result in inversion efficiencies of about 93 % and 50 %, respectively. A perfusion map demonstrating the performance of the above design in creating perfusion contrast in the whole brain is shown in Figure 1b. It should be noted that the inversion efficiency at the vertebral artery strongly depends on the experimental conditions, e. g. if the labeling gradient is reduced to 1 mT m^{-1}, an inversion efficiency of about 74 % can be predicted [5]. A straightforward step to an increased penetration depth of the B1 field decreasing the intersubject variability of the inversion efficiency at the vertebral arteries would be a circularly polarised B1 field. This can easily be achieved by a 90 ° RF phase shift between the two circular surface coils.

References

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