SAR Evaluation of 7.0 Tesla Perfusion Imaging with Arterial Spin Labeling Coil

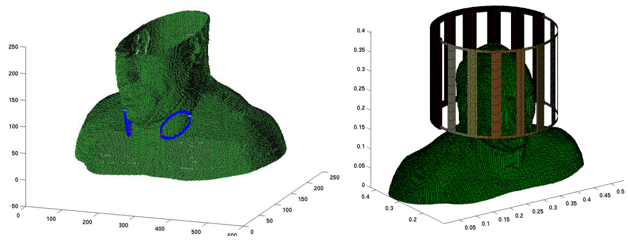
S. Wang[1], H. Merkle[1], and L. Talagala[1]
[1]LFMI/NINDS/NIH, Bethesda, MD, United States

Introduction

The Continuous Arterial Spin Labeling (CASL) with a separate neck labeling coil is an attractive noninvasive approach for human whole-brain perfusion studies (1). Since the labeling coils are normally positioned very closely to the neck, their safety issue needs to be carefully investigated in order to meet the FDA guidelines. This is especially true at high-field, where power deposition is more a concern than at low-field. Indeed, the SAR of CASL neck labeling coils needs to be considered in conjunction with the transmit volume coil, which also deposit power in the neck region. In this study, we examined the safety of neck labeling coils at 7.0 Tesla by using both numerical simulations and experimental data.

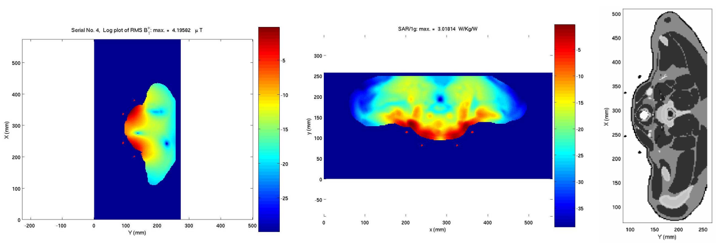
Methods:

The Finite Difference in Time Domain (FDTD) and the Time-Domain Finite-Difference/Finite-Element (TD-FD/FE) hybrid method were applied (2). The 2x2x2 mm^3 human model was created based on the National Library of Medicine's Visual Man Project. The CASL labeling coil is modeled by pure FDTD method (Fig. 1a). It consists of two elliptical loops angled at 90 degrees. Each loop has 66-mm major axis length and 46-mm minor axis length. Two trimmer capacitors are placed at the ends of the major axes. The labeling coil is positioned next to the neck with a 5-mm thick foam. The 16-element shielded high-pass birdcage coil (Nova Medical, Inc.) was modeled with TD-FD/FE hybrid method, in which only the curved coil structure was modeled by the Finite Element method while the rest is modeled by finite-difference method (Fig. 1b). The birdcage coil is 30-cm in diameter and 25.4-cm in length, with each rung of 2.54-cm wide. Coil tuning was performed by using 32 equal-valued capacitors on the upper and lower endrings. The birdcage coil is positioned according to experimental setup, i.e., the head being at the center and the lower-endring being slightly lower than the nose. Local SAR values were calculated by averaging RF power within a 1g region - around each cell.



(a) (b)

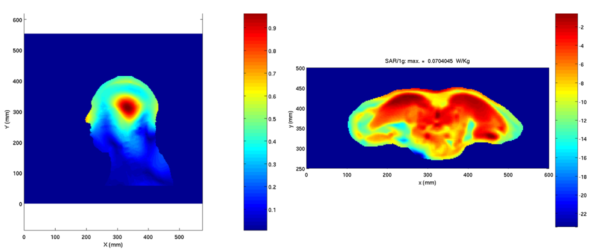
Fig. 1. Computer model of the CASL coil (a) and the 16-element high-pass birdcage coil (b).



(a) (b) (c)

Fig. 2. Logarithmic plots of B1 distribution (a) and the local SAR of the CASL coil (b). Red spots in air denote the coil. The anatomy corresponding to the peak local SAR is in (c).

Results and Discussions: *(1) The CASL coil*: The logarithmic plots of B_1 distributions of the CASL labeling coil and the local SAR distribution are shown in Fig 2a and 2b. The peak 1g averaged local SAR shown in Fig. 2(b) is 3.0 W/kg, which was normalized to 1 Watt power deposition in the human body. In actual 7.0 Tesla experiment (GE Healthcare), 4.7 Watt power was delivered to the CASL coil. With efficiency about 60%, which was obtained by measuring the loaded and unloaded Q-factor ratio, an estimated 2.82 Watt power was deposited into the human body. With labeling duration of 3s, which corresponds to a 30% duty cycle (TR = 5s, labeling RF applied every the other TR), the peak local SAR is 2.53W/kg, which is below the 8 W/kg limit of the FDA guideline. *(2)The birdcage coil*: We are primarily interested in the additional SAR induced by the birdcage coil at the peak SAR location of the CASL coil during image acquisition. Since the actual coil efficiency of the 7T birdcage coil is difficult to measure, the B_1 and SAR results are all normalized to 1-Watt of total power absorbed by the human body and radiated in space. The saggital B_1 distribution is shown in Fig 3(a) and the logarithmic plot of local 1g averaged SAR on the axial slice where the peak local SAR of the CASL coil occurs is shown in Fig. 3(b). The local SAR of the birdcage coil at the peak SAR location of the CASL coil is about 0.01 W/kg. In actual 7.0 Tesla experiments, a total of 250 Watt power was delivered to the birdcage coil. The maximum overall power duty cycle of the birdcage coil for acquiring five images was 0.32% (5 x 3.2 ms / 5 s). Thus the additional SAR at the peak SAR location of the CASL coil is about 0.01 W/kg, which is very insignificant. Considering the fact that part of the power delivered to the birdcage coil is dissipated on the coil, the actual effect of the birdcage coil is even less.



(a) (b)

Fig. 3. Saggital B1 profile of the birdcage coil (a) and the logarithmic plot of SAR distribution on the axial slice in Fig. 2(c).

Conclusions:

We have studied the safety of 7.0 Tesla perfusion imaging by considering the SAR induced by both the CASL neck labeling coil and the birdcage coil. Results show that with the current experimental setup, the local peak SAR in the neck region is about 2.53 W/kg during labeling and 0.01 W/kg during image acquisition. The effect of the birdcage coil is very small due to 1) its relatively large distance from the neck and 2) its low power duty cycle. Results indicate that CASL perfusion with a neck labeling coil will be possible at even higher fields without exceeding the SAR guidelines.

References:

(1) Talagala et al., MRM 52:131 (2004). (2) K. S. Yee, IEEE T-AP 14:302-307 (1966).